HOW TO DRIVE AN AUTOMOBILE

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CHAPTER I

MOTOR-VEHICLE OPERATION

It is in the operation of a motor vehicle that the quality of the user's knowledge is shown. Operation is the practical experience, while all that leads up to it is theory—good theory, it is to be hoped, but nevertheless of small value except as it becomes supplemented by the proper kind of practice.

The first thing to be done in acquiring an understanding of a car is thoroughly to read up on the subject of motor vehicles, in this way gaining the valuable preliminary information that it is perfectly practicable to gain from text and illustration.

For any specific application, the general instruction that is essential must be supplemented by a careful study of the special instruction supplied by the manufacturer of the particular car that is to be operated, following which the personal instruction of some competent person is by no means to be despised.

Among the very first things that it is essential for the novice to understand before venturing with a car on the common highway are the various, universally-recognized rules of the road.

Every user of a public road owes it to himself as well as to others to observe rigidly all of the rules prescribed by law or established by usage for the guidance of road users. Observance of such rules avoids accidents as well as the giving of offence, which it is obvious would be vastly more frequent were there no such rules, or were the rules there not observed.

When meeting another vehicle, coming from the opposite direction, it is the rule of the road in the United States, France, Germany, and Italy, for both vehicles to keep to the right, each turning to one side of the center of the road. If one of the vehicles is a horse vehicle, or is heavily laden, driven by a woman or child, or otherwise less capable of turning out, it is a matter of common courtesy, though not of law, that the other vehicle should permit it to retain the center of the road and pass it by going clear over to the right, even though this involve running on the poorer part of the road surface.

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what its enforcement avoids enough runaways to justify its enactment, not to speak of the effect it has in calming the fears of the timid.

Steering. Steering is one of the first things to be learned by the novice, many good instructors insisting upon it being the very first, telling the would-be driver to learn to steer before attempting to learn even the most fundamental things about controlling the power plant.

If the help of a competent instructor can be had, it undoubtedly is a good idea to learn first to steer. To this end, the instructor may do the driving, while the beginner holds the steering wheel and controls the direction of the car's travel long enough to become familiar with this part of his work.

Steering an ordinary car, at ordinary speed, whether it is controlled by wheel, lever, or tiller, is a very simple manipulation, and proficiency in it is a matter of gaining confidence rather than of gaining knowledge.

At high speeds, steering requires more experienced estimation of distance and of other factors, and greater skill and finer judgment in determining just when and how much to move the wheel, but as far as holding the steering wheel is concerned—contrary to an impression that sometimes prevails with the "man in the street"—it is easier to hold the wheel of a car going at high speed than at slow, because high speed tends to make the vehicle keep to its course, much as in the case of a bicycle.

An excellent plan for the beginner, if he lack the services of an instructor, is to find a long, straight and slightly downhill road, free from other traffic, upon which he can coast the car down slight inclines. By previously mastering the principles of clutch and brake manipulation, it will be perfectly safe to start the car at the beginning of the descent and permit it to coast slowly down, no attempt being made to start the motor. The brakes provide a ready means of stopping and of controlling the speed, while meantime the steering may be experimented with until a high degree of proficiency results.

With irreversible steering, there is no occasion for constant or rigid holding of the steering wheel, since the road wheels are locked against derangement of their position from contact with road obstacles. With reversible steering, any glancing contact with the side of a rut, or against other inequality of the road surface will move the road wheels, and perhaps even jerk the lever or tiller out of the operator's hands, if he is not watchful. From these considerations, it is scarcely necessary to urge that

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Sometimes, before reaching the dangerous spot, it is well to apply the brakes enough to slow the vehicle materially, but before the bad surface is actually under the wheels, the brakes must be off again.

The reason that skidding generally occurs at the rear when the power is on, is because of the differential. This mechanism, provided to permit one rear wheel to rotate faster than the other when it has to go a greater distance, as in going around a curve, may also permit one rear wheel to rotate faster than the other when there is a difference in the resistance the two wheels encounter in their adherence to the road surface. This condition may arise when one wheel strikes a muddy or slippery place while the other is upon a dry surface, with the effect of "spinning" the wheel on the slipperiest spot, while the other continues to rotate at its normal speed. Then, if the other wheel also run onto a slippery surface, the tendency of the first wheel to revolve faster may be sustained long enough to swing the rear of the vehicle sidewise, the driving action having been greater on one side than upon the other.

Similar skidding may occur as the result of applying the rear-hub brakes, if one of them goes on harder or sooner than the other, in which case one wheel will be retarded while the other is still running free.

After skidding has commenced, it probably is continued largely by the tendency of the rear of the car to run past the front, so to speak, the moment there is the slightest deflection from a straight line. This tendency is especially marked with cars that carry most of the weight on the rear wheels.

The best way to handle skidding is to avoid it, by always driving carefully on slippery roads and in turning curves, and by never changing the course of the car except when it is going at a much slower speed than the speed of straightaway running. And in any case, it is always desirable to change from the straight course very gradually, avoiding sharp turns as much as possible.

Deft manipulation of the steering wheel by an expert operator often will neutralize a well-developed skid, by maintaining the car in approximately its original line of onward movement. Thus, if the front wheels are steered in the direction in which the rear wheels are skidding, the tendency of the vehicle is to stay parallel to its original line of movement, ready to resume it as the skidding terminates.

Sometimes increasing or decreasing the speed, by accelerating or retarding the engine, will neutralize skidding, provided that

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No adjustment should be altered or changed, however, unless it is determined for a certainty that readjustment is required.

The next step is to memorize the functions of the various levers and pedals that require manipulation in the course of ordinary use. If the student has previously owned a car of similar make, this will be comparatively simple, and, even if he has had a car of different make, his experience will help greatly by suggesting the purposes of various details of the new construction. It will be necessary, however, firmly to fix in the mind differences in operation that the new car presents over the old, since otherwise the earlier knowledge may cause embarrassment and possibly dangerous confusion.

Before actually going out on the road, some consider it not a bad idea for the novice to jack the machine up on some solid support and try running it with the drive wheels revolving freely in the air. By this means, it may prove possible to gain a very thorough idea of power-plant operation without the risk that comes from taking a new car out on the road. Be sure the support is solid.

When real road running is decided upon, it should be conducted, as previously advised herein, upon a good road and at an hour or in a place where there is not likely to be interference by other traffic. The start should be made on a straight stretch, with the car on one of the lower speeds. One of the first important things to master is starting and stopping. These once learned, danger can be avoided whether the other elements of operation are understood or not.

Judicious application of the brakes, at different speeds, with the result of learning just how much pressure is necessary to slow and how much is necessary to stop, will rapidly give the confidence necessary to quick progress.

Operation of Gasoline Machines. Gasoline cars of present-day types invariably are fitted with clutches of some sort, whereby the engine may be disconnected from the transmission. Knowledge of how to release the clutch—usually by pressing upon the clutch pedal with the foot—is one of the first essentials in the beginner's education. When the use of the brake is understood, and the fact that the clutch disconnects the engine from the drive is realized, the danger of accident through inexperience is practically eliminated.

A good clutch can, by careful manipulation, be permitted to

slip almost to any desired extent. This, even without the use of the change-speed gear, permits considerable control over the speed of the car by letting the clutch in slowly and lightly and by releasing it frequently. Even with the best clutch, however, this method of drive will propel the car with a series of jerks rather than smoothly, besides occasioning rapid wear, so it is to be recommended only as an expedient for the beginner, rather than as good practice for the experienced operator.

On most cars, the pedal to the left is the clutch pedal, the one to the right actuating a brake that applies on the transmission or the rear-wheel hubs.

With many cars, the brake pedal is arranged to release the clutch also, so manipulation of it alone is sufficient to stop the car absolutely, whether the engine is running or not.

Before attempting to start a car, it is well to remember that the fuel tank must be filled—using a funnel with a strainer or, preferably, straining the gasoline through a piece of chamois leather, which has the peculiar property of holding water while letting gasoline through.

After the gasoline tank is filled, the water tank must be filled. If there is a separate tank for water, this may be filled directly through the filling cap provided. Most modern cars carry water only in the radiator, the water-jackets, and the piping of the cooling system, in which case the system will be filled through the filling cap on top of the radiator.

The lubrication is another essential. All grease cups must be packed with proper lubricant; oil or grease should be in the change-speed gear case; oil should be in the reservoir of the lubricating system; and, usually, it is necessary to have oil in the engine crankcase. In filling tanks, care always should be taken to use the proper liquid. Many inexplicable difficulties have arisen through the use of gasoline containing dirt, water, or other impurities; while lubricating oil with a trace of grit in it is certain to be more detrimental than beneficial. Likewise, water containing dirt or lime may completely obstruct a radiating system or a steam boiler.

Always before attempting to start the engine set the emergency brake, and be sure that the change-speed gear lever is in a neutral position, because if it is not any attempt to crank will result in moving the car, besides involving an amount of exertion that will immediately point to something wrong. Next turn on the fuel and switch on the ignition current. Prime the carbureter by pressing down on the small projecting rod pro-

vided for this purpose. When the carburetor overflows, as will be indicated by a slight drip, there is enough fuel in it to vaporize and furnish a mixture. Now crank slowly, making sure that the ignition is in the starting position, since otherwise a back kick may cause serious consequences.

MANIPULATION OF SLIDING GEARS

With the motor running, the learner may place himself in the driver's seat, release the brake and then the clutch, and move the change-speed lever quickly to the low-speed position. Be absolutely sure that the clutch is held disengaged while this manipulation is effected, and not until the lever is locked solidly into its shifted position may the clutch be permitted to engage gradually, whereupon the car will start on its lowest speed. All this, of course, applies only to cars with sliding gears.

Some cars are fitted with interlocking devices, which make it impossible to manipulate the change-speed lever except when the clutch is out.

For the novice, it usually is best to change speed sharply in both directions, whether in going from a lower to a higher speed, or coming from a higher to a lower speed. With most types of sliding gears, changing from a high speed to a low is more difficult than from low to high, though sometimes just the opposite is the case.

Changing up from a low speed to high requires that, after the speed engaged is disengaged, the motor be retarded before engaging the next higher speed. Changing down—from a high speed to a lower—requires that the motor be speeded up or the car retarded, or both, during the time the clutch is out, and before it is attempted to engage the next speed. By fixing these simple facts in the mind, and paying attention to them in changing speeds, there will then be acquired most rapidly that instinctive appreciation and "feel" of the conditions of gear rotation, which with the expert operator makes possible the sliding of the gears into mesh almost without clash or jar, and always without the danger of stripping that so frequently befalls the careless driver.

The reason that changing from a low speed to a higher is sometimes more difficult than the contrary, is that the gear connected with the clutch is running slower than the gear with which it is to engage, so that the slowing of the vehicle tends to increase rather than to compensate for this discrepancy in the motion.

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vehicle speed immediately before shifting, just when to move the lever.

As a general rule, plenty of time should be taken to consider the necessity for speed changing and the moment for doing it, but when it is to be done, it should be done by a sharp, quick movement.

Continual practice, under favorable conditions, is the only means of learning the exact effect of the change-speed-gear, the brake and clutch pedals, etc.

No motorist is qualified to give his car the best engineering care until he has mastered the control of the gears, the control of the clutch, and the control of the brake. These understood, he may with reasonable safety attempt to go anywhere on reasonably good roads, fairly clear of traffic, and at reasonable speed, until he has attained a greater degree of proficiency.

MANIPULATING PLANETARY AND INDIVIDUAL-CLUTCH GEARS

With planetary or individual-clutch gear systems, one single lever usually controls all speeds, requiring only a simple forward or rearward movement, made rather deliberately, to bring the various gears into play.

A slight down grade, on which a car will barely coast, is as good a place to gain preliminary practice in gear shifting as it is for learning to steer.

When a car is proceeding on its high gear, unless it is fitted with an engine much more flexible than is ordinary, it will be impossible to go slower than four or five miles an hour without dropping to a lower speed, or without slowing the car by intermittently releasing the clutch so that it can slip more or less. Consequently, the highest speed of most cars is not suitable for travel in traffic.

Hill-climbing, or running over sandy or muddy roads, usually requires the use of one of the low gears, because of the harder pulling. Whether or not the very lowest gear is necessitated is determined by the power of the engine and by the number of speed changes that are provided.

The point at which a road becomes so steep or the running so heavy as to require a change in the gear ratio, can be determined only by experience and experiment. And it is only the motorist who has done much driving who is really an expert in this particular.

If it is attempted to climb too steep a hill on the high gear,

the motor gradually will "stall"—stopping because of the low speed at which it is permitted to run, coupled with the excessive demand upon it for power. By retarding the spark, it can be made to run as long as possible upon the high gear, but when it finally slackens in spite of this, change must be made to a lower gear.

With an engine that has automatic governing of the throttle or of the ignition, much information as to the best time for the gear changing will be conveyed to the trained ear by the sound of the governor. With a car running at one of its lower speeds, a frequent "cutting out" by the governor indicates that the going is so easy as to make a shift to the higher speed desirable. Conversely, when the engine is pulling hard, if it labors to the point where the governor is opened to the limit, danger of stalling is imminent and the necessity for changing to a lower speed is imperative.

In changing to a high speed, always wait until the patch of bad going or the crest of the hill is surmounted. The engine is almost certain to be stalled if the high gear is thrown in too soon after a period of using a lower gear.

CONTROLLING THE MOTOR

The most approved means of controlling the speed of a gasoline engine consists in the manipulation of the throttle, whereby more or less mixture is permitted to be aspired by the cylinders, this control being effected either by a pedal or by a hand lever, or by both, at the option of the driver. Some of the best modern cars are capable of a variation in speed on the high gear of from two and one-half to fifty miles an hour.

An older scheme is to control by varying the point of ignition, but this is now considered a very poor way, and control of the ignition is now used only to secure the best results in the way of fuel efficiency. Thus, instead of being a means of changing the speed, the ignition timing is set to conform to speeds that are determined by other factors.

The spark must be well advanced when the engine is running fast, and retarted when running slowly, without regard to whether it is desired to run fast or run slow, or to pull hard or the reverse.

The exact extent of spark advance suitable for a given car is determined not only by the construction of the car, but also under the conditions by which it is operated, the adjustment of the ignition apparatus, the strength of the current that is supplied, etc.

The only general rule that can be followed is to keep the spark advanced as much as is possible without making the engine "pound," from backward-acting explosions early during the compression stroke. Advance the spark until this pound is heard—it being readily recognized by the trained ear of the experienced operator—and then retard just enough to stop the pound. If the ignition is retarted too much, it will be shown by a material falling off in power, with consequent slowing of the vehicle.

The only conditions under which speed may be justifiably governed by retarding the ignition is when it is desired to run exceedingly slow.

From the foregoing, it will be understood that the control of a modern gasoline automobile, while running, involves first the manipulation of a steering device, a throttling mechanism, and a brake, and secondly, of a clutch and of a change-speed gear.

Certainly the ideal motor vehicle, of any type, is that in which the controlling devices are as few in number as possible. There is, however, no particular objection to extra levers and pedals, provided for extra convenience or safety, but not ordinarily likely to need manipulation, as in the course of regular running. Those for the latter purpose should be few in number and convenient in location.

STARTING THE MOTOR

Half of the ability to make a repair or an adjustment is the ability to discover its necessity. Never tinker with different parts of the mechanism, nor labor with the starting crank, without first bringing a little intelligent consideration to bear on the question of what is the most likely cause of the difficulty. It is of little use to turn an engine over and over by the starting handle in an effort to set it going. If the engine will not start with one or two complete turns, the chances are that there is something radically out of order, requiring intelligent attention. With the carbureter giving a correct mixture, the ignition system affording a hot and effective spark, and everything else apparently all right, it should be as easy to secure an explosion on the second stroke as on the hundredth. So, if an engine will not start with the second or third turn of the crank, it is likely not to start with three or four hundred turns of the crank; consequently it is better to find out the trouble than to turn the crank indefinitely.

Cranking is an art that is essential for the new motorist to become proficient in. There is more to this apparently simple manipulation than there seems to be at first sight.

The novice will realize this better after he has seen some one physically much weaker than himself start an engine that he is totally unable to throw over by main force. The point is simple—no attempt should be made to turn an engine over by main force. Instead of so doing, there is a sort of knack in getting the flywheel to oscillating, in periods of gradually increasing amplitude, until finally with a last powerful acceleration, it is carried over against the compression, as much by the momentum imparted to the flywheel in gradually increasing increments as by the main strength exerted through the operator's arm and hand.

Previous to cranking, be sure that the ignition is retarded so as to make back kicks impossible, unless this is done automatically by some interlocking mechanism provided for the purpose.

Further to guard against back kicks, it always is a good plan to pull up on the starting crank, rather than to push down upon it, since then if a back kick occur the crank will be pulled out of the hand, rather than thrust up against the stiffened arm.

It is a good point to get the engine to revolving with considerable speed just before the point of highest compression is encountered. Many skilful operators are able by following this plan to crank an engine safely with the spark more or less advanced, without receiving a back kick. The reason is that an engine is more likely to be reversed by a back kick when it is turning very slowly than when it is turning fast. In fact, it is solely the speed at which the motor runs that prevents it from being reversed in normal operation by advancing of the spark.

If the engine will not start, perhaps the fuel tank is empty, or it may be that the clutch is in engagement, that the brake is on, or some other equally simple point neglected.

Be sure, after the motor is running, that the lubricator is turned on and working properly.

In starting a cold engine, the steam almost always present to some extent in the charges of mixture may be condensed in the compression chamber to an extent sufficient to short-circuit the spark plug. If the engine can be warmed up, this trouble will vanish.

A very simple means of starting a gasoline engine in cold weather, when all other means fail, is to fill the waterjackets with boiling water. This will warm the cylinders and the portions of the mechanism immediately adjoining to such an extent that carburetion and ignition will be more easily effected. The applica-

tion of cloths wrung out in hot water to the outside of the carbureter serves a similar purpose.

Vigorous cranking of an engine in cold weather sometimes is useful as a means of starting, because of the heat it generates by the compression of the gases. This is a very laborious process, however, and if the compression-release taps are left open much of the heating effect will be lost.

GENERAL

Every car has its own peculiarities. Therefore one of the first things to do is to learn the peculiarities of a new car. Even different cars of the same make will be found to possess their own especial quirks and foibles.

It is not enough merely to learn the general manipulations that are necessary to the operation of a given car. It is necessary also to learn the exact degree to which manipulating devices may be moved in the effort to produce a given effect. Such knowledge can come from practice and from practice only, though good theory is the best kind of a basis upon which to found it.

For the novice who has yet to learn how his engine works, with it running but with the car standing still, it is well to try the various engine-controlling devices—advancing and retarding the spark, opening and closing the throttle. In this way, a very fair idea can be gained of the effect of the different controlling means upon the action of the engine. Sudden starting, accelerating, retarding, or stopping, seriously strains the mechanism of a car and always is avoided by a careful operator. Only a serious emergency justifies such practices, which are sure to shorten the life of a machine materially.

It always is best to ascend a hill on a gear low enough to insure completion of the climb. It is altogether preferable to take a hill slowly, rather than to risk having to pull up or change gears on it. With planetary or individual-clutch change-speed gears, which make changing from one speed to another very simple, this does not apply to the same extent that it does with sliding gears, it being sufficient with them to make the required change before stalling of the motor occurs.

In changing to a higher gear, the car should be run as fast as it may on the lower speed before the shift is made. If the car is not running fast enough before attempting to change, the gear is very likely to shift with the utmost difficulty.

Starting a car with one of the higher gears in mesh never

should be attempted, unless the engine is running at very low speed and the operator is thoroughly competent. Otherwise there will be great danger of stripping the gearwheels. And in no case should the clutch be one that engages abruptly. It should engage smoothly and softly, with almost imperceptible grip, going into place with a gradually diminishing slip, until it is turning uniformly with the flywheel.

Locking the driving wheels by a violent application of the brake will not stop the car as quickly as will an application that gradually augments in intensity, retarding the wheel rotation until the vehicle motion is brought to a stop. Violent braking of the wheels will cause them to slide along the ground, with the result of heating the rubber tires and causing the material of them to act almost as a lubricant, permitting the vehicle to slide along the surface of the road with comparative freedom, not to speak of the destruction worked upon the tires.

Nothing is more severe on a motor vehicle than the spectacular stopping and starting often indulged in by ignorant drivers, in mistaken efforts to show off.

Though many motorists leave the engine running while the car is standing, to avoid the bother of starting it again, this generally is a bad plan, except for momentary stops, because it causes waste both of fuel and of lubricant, besides giving extra wear and tear to the different portions of the mechanism, not to speak of the possibility of a disastrous start through the tinkering of some inquisitive bystander or small boy.

The gasoline supply from the tank to the carbureter invariably should be shut off when anything longer than a momentary stop is made. This avoids waste of fuel and flooding of the carbureter through possible faulty functioning of the needle valve.

In many cases it is inadvisable to have the shut-off tap near the carbureter, since if it is near the fuel tank instead, there is then no danger of the length of pipe from the carbureter to the tank becoming filled with air in such a manner as to delay starting. To avoid danger of fire, it is perhaps well to have both taps, normally keeping the one near the tank open.

The utmost economy of fuel and of ignition current is secured by cutting off the fuel and switching off the ignition on every downhill that permits of coasting.

Operation of Electric Machines. In the matters of steering, braking, and the general precautions that should be observed by all users of the highway, the operation of an electric machine is the same as that of any other.

The manipulation of the power plant is very different, however, but this difference is in the direction of simplicity in almost every particular.

The controller of an electric vehicle always should be moved sharply from notch to notch, because otherwise arcs will form at the slowly-broken contacts with the effect of rapidly burning them away, thus causing the controller to wear out quickly. Some controllers are so constructed, however, that no matter how slowly the controller handle is moved, the contacts will separate sharply. Controllers of this sort are, of course, less easy to abuse than the simpler type.

The contact members in switches and controllers always should be bright and smooth. If they are scored or pitted, it indicates arcing, a difficulty occasioned by careless operation or faulty adjustment, and one that should be immediately corrected.

The handle of a controller should be moved as infrequently as possible when climbing hills or pulling over heavy roads, because under these conditions a much heavier current than ordinary is passing through the controller, and is correspondingly likely to lead to abnormally severe arcing if the contacts are broken.

The current always should be shut off in the motor of an electric vehicle before any attempt to stop by an application of the brakes is made. If the brake is applied inadvertently before the power is shut off, and the motor is thus stopped or caused to revolve slowly, while current is flowing through it, burning out is almost certain to result.

Also if the armature of a motor is suddenly brought down to a very slow rate of rotation, the flow of current continuing through it is likely to burn out.

For the same reason, sudden slowing down due to striking an exceedingly severe hill or heavy going, or brought about by the towing of another vehicle, tends to pull down the speed of the automobile at the same time permitting too much current to go through it. This will cause burning out in the same manner as in the preceding cases.

Reversing an electric motor while the current is going through it, so as to cause a sudden stop, is possible and very effective, but it must be avoided except in serious emergencies, because it causes severe stresses upon the whole driving gear and may burn out not only the armature but the insulation of the field coils of the motor.

Operation of Steam Machines. With a steam automobile,

there rarely is any change-speed gear, so the running of such a car reduces itself simply to competent operation of the power plant.

The vehicle is stopped and started and its speed is controlled by simple manipulation of a throttle, taking the form of a small lever or a small wheel. One of the most popular steam machines has a small wheel immediately above the steering wheel, for manipulating the throttle.

Reversing is effected by a special reversing lever with a link motion similar to that used for the same purpose on a locomotive. Unlike the case with the locomotive, the point of "cutoff"—the point in the stroke at which live steam ceases to be admitted to the cylinder—cannot be varied by such fine gradations in the average steam-automobile mechanism. This is because the automobile reversing lever works over a sector provided with comparatively few notches.

The locomotive system of setting the valve gears so as to give the cylinders live steam practically during the full stroke upon starting or on a heavy grade, and then, when the power demand lessens, bringing the cutoff lever nearer the center of the quadrant, is all very well for large power units and heavy construction. But in a motor vehicle the cylinders are so small that there is too much cylinder condensation to permit of satisfactory results when close cutoff regulation is attempted. Besides this, there is more lost motion between the engine of a steam motor and the driving wheels than there is in the ordinary direct connecting-rod drive of the locomotive, so an attempt to work the steam expansively to too great an extent is very apt simply to cause rattling and pounding.

Doubtless the best plan is for the motorist to determine experimentally what cutoff regulation his machine will stand, and to run accordingly. This will reduce fuel consumption.

It is a particularly bad plan to start a steam vehicle suddenly, not merely because the racking stresses due to sudden starting are bad for any sort of motor vehicle, but because a steam machine, after standing, is likely to have water condensed in the cylinders. This being the case, a sudden start is likely to produce pounding upon the incompressible liquid, resulting disastrously even to the extent of blowing out a cylinder head. By starting slowly, the cylinders are warmed up and any water that may be in them is vaporized into steam before it can cause trouble.

Speed. There is much popular misconception as to the dan-

gers attendant upon the speed at which motor vehicles are capable of going.

One of the greatest merits of the motor-car is its capacity for sustained rapid travel, and, while it is not to be denied that there are certain dangers inseparable from all fast travel, these dangers are ordinarily much misrepresented and misunderstood by the opponents of the motor-car and that class of the public which always is intolerant of innovations.

It is a fact perfectly demonstrable that fifty miles an hour with a well-built machine, in competent hands and on a clear and perfect road, may be far less dangerous than six or eight miles an hour with a poor car in the hands of an inexperienced driver, in crowded traffic.

There are circumstances when speed may even become an absolute factor of safety, since there are times when the least likelihood of accident is plainly to be insured by moving a car most quickly from one point to another.

One of the best arguments against excessive and unreasonable speed, taking into account road conditions, is the injury it is certain to work to the tires and to the mechanism of the car.

Careless or fast driving on rutty roads, especially if they are frozen, always is inadvisable. Such driving not only is damaging to wheels and tires, but may even cause actual danger to life and limb by occasioning a puncture or a road shock that will deflect the car from its straight onward course.

Coasting down hills with the high speed engaged, at a rate much greater than that at which the car is designed to run when pulled by the engine, has been known to break flywheels, and especially the armatures of electric cars, even in cases in which the latter were strengthened by wrappings of steel wire or steel bands.

An electric motor normally runs at a very high speed, and therefore is geared down considerably to the axle. Consequently, if the vehicle be run very fast, as in coasting, it will drive the motor at a speed that may become truly enormous, with a consequent centrifugal force that is certain to cause trouble.

The stresses on axles, springs, etc., also are much increased by higher speed, these stresses increasing about as the square of the velocity. From this, it can be seen that the dangers of breakage are very much greater at the higher speeds. Even the difference between fifty and sixty miles an hour, because of the squaring of resistances, is much greater than would at first appear, and it is a somewhat interesting engineering fact that from

forty-five to fifty miles an hour is not very difficult to attain nor exceptionally unsafe, while sixty miles an hour is far past the danger point and requires for its accomplishment great horse-power and the best of construction.

All the dangers of speed that exist in normal straightaway going are vastly increased on curves. The destructive action on the tires is particularly heightened, and the wheels are subjected to side stresses much greater than those they encounter in ordinary service.

Even the reckless motorist, who may go fast on straightaways, will, if he is an expert, go slowly around curves. No skill nor quality of car can wholly avoid the dangers that are inevitable with fast going around curves.

The most pronounced effect of high speed on the vehicle control is to make the steering very easy. At the slightest touch of the steering wheel the car answers with a surprising readiness. But in this very facility of response lies a danger that is not at first apparent. It can be best explained by an example.

Take the case of a car going at sixty miles an hour along a straight road, twenty feet wide. This means, if the car is of ordinary tread and is kept on the crown of the road, that it must run about seven and one-half feet to one side or the other before it possibly can go in the ditch. This, in turn, requires that the road wheels be held at an angle of about one-half of an inch out of straight, for the car to go into the ditch in an onward travel of 270 feet. This seems, and at low speed is, a great enough distance to guard against the remotest possibility of danger, but since a car going at sixty miles an hour is traveling 88 feet a second, it means that a derangement of the steering to the extent of one-half of an inch will put the car in the ditch in about three seconds, unless the wrong steering is corrected within that time.

ESTIMATING SPEED

In the absence of a speed indicator, it is possible only to estimate the speed by keeping track of objects definite distances apart along the road, using a watch or clock to note the time taken in traversing the chosen units of distance.

In a city, by learning how many blocks there are to a mile, it is very easy to judge speed. In the country, a similarly fair idea of the rate of travel often may be gained by counting the telegraph poles. Along railways, these usually figure about twenty-eight to the mile.

On the continent of Europe, practically all of the main highroads are marked with kilometer stones, placed .62135 of a mile apart. In some sections of the United States, milestones are found, though they rarely are maintained with equal care and placed as conspicuously as in the case of the splendid government highroads of most European countries.

Touring. Besides the things that are obviously necessary, there are many minor details of equipment that it will profit a motorist to give considerable study to, so that he may be always sure of having in his car all that is likely to be required in any circumstances that may arise.

Besides a full equipment of tools, a supply of spare parts should be carried along. These will be of two classes—those particularly likely to be needed, and those so small that they may be just as well taken along as not.

THE USE OF MAPS

Maps are indispensable to the motorist who ventures out of familiar territory. Even in territory with which one is supposed to be acquainted, a map often comes in convenient.

There are two principal kinds of maps available for use by the motorist—general maps and detail maps. The first, as their name implies, show only the general outlines of a country, with the larger cities, watercourses, etc., denoted upon them. The second show the details, even down to every minor road in the case of the best maps obtainable.

Practically all maps are made with the upper side the north, the west at the left, the east at the right, and south at the side towards the reader. With some maps, this rule is not followed, in which case there usually will appear somewhere on the map arrows denoting the cardinal points of the compass.

In travelling through strange country, the best results will be obtained by carrying a general map of the whole country, with detail maps of smaller sections, to be substituted for one another as the journey progresses.

RUNNING AT NIGHT

What is said in a preceding paragraph about running over bad roads or in unfamiliar country applies also to running at night, even in familiar country, and applies with double force at night in unfamiliar country.

The best safeguard for night running is a full equipment of

good lamps. Besides a tail lamp, showing red to the rear, there also should be side windows in this or other lamps showing green. Two or more lamps are required in front—sufficient not only to provide ample forward illumination, but also sufficient to constitute a reserve. One large acetylene headlight, mounted on a swivel stand so as to point readily in any direction, is very popular, though this light will be found in every way more serviceable if it is mounted higher up than is usually the case. Instead of on the dashboard, it should, if possible, be placed on top or immediately beneath the canopy top, if such is used.

A light set too low makes every minor hollow in the road seem like a deep pit because of the black shadow cast. If carried higher up, it will illuminate the bottoms of these hollows and show the road much more clearly.

EFFECTS OF WEATHER AND ALTITUDE ON MOTOR VEHICLES

Taking a motor from sea level to an altitude of 10,000 feet involves using air in the engine cylinders at an atmospheric pressure ranging from 14.7 pounds down to 10.1 pounds to the square inch. This marked drop in atmospheric pressure, with all the difference it implies of fully thirty per cent. in the actual quantity of air inspired by the cylinders, cannot fail to have a very considerable effect upon the power and the compression of a gasoline engine, so it often is found advisable to reduce the compression space in such an engine when used in high altitudes. Most carbureters will require some adjustment in the course of any material change from one level to another.

CAREFUL DRIVING

Every motorist should make it a point to observe the road laws and regulations of the locality through which he passes. While many of these laws are at present as absurd as they are severe, and often so inconsistent that it is impossible to observe them to the letter, a point may at least be made of observing them in spirit. Remember that the way to eliminate the evils of a bad law is to bring about its repeal, not its violation.

And if arrest and fining, and possible imprisonment, not to speak of inconvenience, are to be made the consequence of even a technical evasion of law, surely it is by all means better to concede something to the avoidance of possible trouble.

CHAPTER II

TIRES

As the portion of a vehicle that comes in contact with the road, a tire is one of its most indispensable details. Primarily designed to resist wear, at least two important functions—one, the cushioning of vibration, and the other, the smoothing out, so to speak, of the surface of movement—have been within a few years added to the purposes of the tire. Another function, the adhesion of the tire to the road surface—its tractive efficiency—has been greatly developed. These various advances in tire construction, which have been chiefly due to the substitution of soft for hard tires, have little less than revolutionized a detail of vehicle construction that existed, well-established and almost unchanged, for thousands of years.

The modern pneumatic tire, as well as its immediate predecessors and present rivals—the solid rubber and the cushion tires—were developed contemporaneously with the pedal-propelled bicycle. This light vehicle, which necessarily has to operate with a minimum of power to conserve the muscular effort put forth by its rider, and which also has to be very free from vibration, even when used on rough roads, absolutely requires a soft tire. As the motor vehicle has developed, the tire found so highly efficient for applying muscular power to vehicle driving has naturally proved successful in applying mechanical power to the same purpose.

Tires and Road Surfaces. Were all roads perfectly smooth, perfectly smooth and hard tires would be best for use on them. This is evident in the fact that railway lines—which are for all practical purposes simply narrow strips of hard, smooth road—work best in conjunction with wheels made of material similarly hard and smooth. As it is not practicable, however, to have the average common road perfectly smooth and hard, it follows that ordinary hard tires traversing such a road must rise and fall over every slight inequality of surface. Under such circumstances,

much power intended to produce onward motion is expended in producing this succession of slight lifts. Practically, very little of the power thus wasted is recovered as the wheels drop down from the minute obstruction. Consequently a hard tire progresses in a series of power-wasting bumps over any but a theoretically perfect road.

With a soft tire, small hard objects and inequalities in a road simply mold themselves momentarily into the tire tread, without materially raising or lowering the wheel. The effect of a pneumatic tire, or, to a lesser extent, of any soft tire, is to smooth out a rough road surface—not by removing its inequalities, but by perfectly adjusting itself to them. In Fig. 1, it is shown how a hard tire with an irregular instead of a perfectly circular outline, must necessarily run level and smoothly on a road surface of exactly corresponding irregularity.

A pneumatic tire, by virtue of its soft and perfectly deformable surface, presents always an irregular outline where it is in contact with a road, corresponding in a considerable degree to the irregularities of such road. It must, therefore, run very smoothly over any irregular surface, just as the permanently irregular tire does over a surface exactly adapted to it. As a matter of fact the profile of the tire shown in Fig. 1 represents what would be the appearance of a pneumatic tire just run over the same surface—having a length equal to the tire's circumference—were it to remain deformed instead of immediately recovering its original outline. Fig. 2 shows how a given road surface, made irregular by small inequalities differently affects the running of hard and soft tires.

A further advantage of soft over hard tires is that their flattening, or deformation, presents a larger surface to the road than would be presented by hard tires of the same size, thus lessening the liability to sink into sandy, muddy, or other soft surfaces, and increasing the area of contact available for tractive or braking purposes. The tendency to wear also is reduced in proportion as the weight of a vehicle is supported over a large rather than over a small tire area.

Care and Repair of Pneumatic Tires. The care and repair of pneumatic tires is rather complicated, but should be understood by every motorist, since tires are the most vulnerable parts of a car, and even the best tires are certain to require more or less regular and experienced attention. It is established, in fact, that it is better to build tires efficient and easy to repair, rather than ones guarded against injury by objectionable design.

Every tire manufacturer makes a specialty of supplying full instructions, as well as small kits of tools, for the repair of his tires in even the most serious emergency. Every motorist should religiously keep on hand such instructions and repair outfits.

Injury to pneumatic tires results from wear; puncture; bursting from violence; rotting of the fabric from moisture or rust; oxidizing of the rubber from long exposure to heat, dry air, or sunshine; heating from running; rim cutting, and cutting of valve stems.

Any sort of injury to a tire requires repair. Badly worn tires can only be made useful by having new treads or additional rubber vulcanized upon them; punctured tires require patching; burst

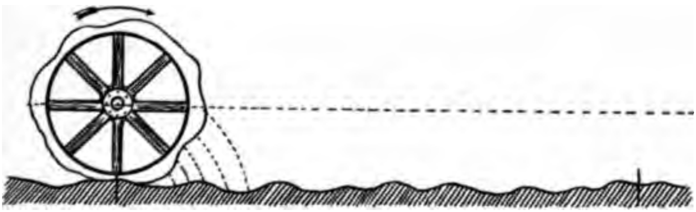

FIG. 1

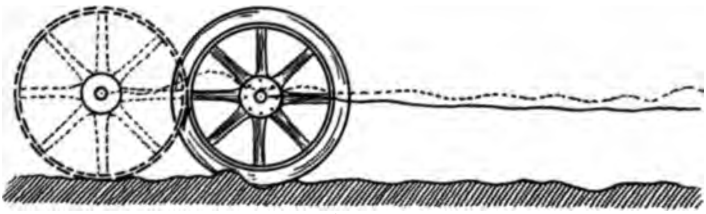

FIG. 2

tires also require patching, if the injury is not too serious to permit it; tires with rotting fabrics must have prompt attention if they are to be saved; the same may be said of oxidizing tires. Heating from running is apt to result in a softening of the rubber and consequent "blistering." Rim-cut tires immediately should have further injury of the same sort prevented; and valve-stems cut partially or completely off must undergo prompt renewal or repair.

Injuries to pneumatic tires may be divided into two classes—those immediately rendering them unserviceable, and those simply

contributing to their final breakdown. It obviously is necessary for a motorist immediately to repair injuries of the first character, and it is generally well to give prompt attention to the others.

Probably the most common injury to a tire is a puncture. The rubber and fabric of which a tire is composed being very soft in comparison with the hard material of road surfaces, and sharp objects being frequently met with on the roads, it is only to be expected that nails, broken glass, sharp stones, and similar things will from time to time penetrate a tire that is regularly used, and permit the air to escape from it more or less rapidly. This causes the tire to become flat.

Punctures may be either large or small, and may penetrate through the outer casing alone or both through it and the inner tube. A small puncture often permits the air to escape so slowly that the tire does not become entirely flat for some time. The first intimation of such a puncture is likely to be a sharp thumping of the wheel rim against some object in the road, such as the raised rail of a railway track, but will be further manifested, if the tire become very flat, by wobbly and uncertain steering.

Punctures that merely penetrate the outer casing of a double-tube tire, without going through the inner tube, cause breakdown by the undue stress they impose upon the latter. An inner tube being simply for the purpose of rendering the tire air tight, and not being so constructed as to resist pressure, it is readily forced out by the air through any considerable hole in the surrounding casing and then almost instantly stretched until it bursts. Sometimes bursting of the inner tube in this manner is delayed for several hours or even days after the original injury, since the hole in the casing may be very small at first and gradually become enlarged through use or by rotting of the fabric from the effects of moisture.

In repairing punctures that have let the air out of the tire, it is first necessary to remove the tire partially or completely from the wheel. The method of doing this varies according to the make of tire. Many modern tires are ingeniously devised with a view to simplifying this operation as much as possible. With others, especially with those of the well-known clincher type, the manipulation is more complex to the uninitiated, but may be readily performed by an expert.

REMOVING CLINCHER TIRES

To understand the process of removing a clincher tire, a careful study should first be made of its construction. There is the

woven canvas fabric, of from four to ten layers; a tough rubber that covers the outer casing, most of it being concentrated on the tread where the principal wear occurs; the air, or inner tube, which is composed of pure, elastic, and air-tight rubber, of no great strength, however; and there are the flanged edges or clinches of the casing, which hold the tire in the rim. The steel rim, with hooked edges to engage the clinches; the several large-headed bolts or clips that press the clinches tightly into the rim, thus helping to hold it in place, and preventing it from creeping on the rim, also constitute a part of the complete tire. The stems of the clips are threaded to receive the nuts, and washers between the rim and the nuts, to facilitate tightening the latter, and there also is a canvas and rubber flap, attached by one edge to the inside of the outer casing, and extending under the inner tube to protect it from becoming injured by contact with the clip heads or the rim surface.

At the present time, a protection strip, attached to the rim or vulcanized to the lower side of the inner tube, is perhaps more commonly employed than the flap for large tires.

In removing tires of clincher type, having protection strips instead of flaps, first all the air should be permitted to escape from the inner tube by opening the valve—unless the tire has been previously deflated by a puncture. The cap of the valve should be left off if necessary to permit the valve-stem to pass through the rim. Then all the clip nuts should be unscrewed until they drop to the ends of the clip stems. This done, press the clips back into the casing, leaving the clinches free so that one of them may be removed by pressing it out of the hooked edge of the rim, for which manipulation a tire lever should be used. If the tire has been in place for a long time, it may stick so tightly to the rim as to need loosening all around on both sides with a tire lever.

The tire once loose from the rim, it should be pushed well over with one hand, and the lever inserted under the clinch with the other. With the lever properly in place under the edge of the clinch, it should be pulled back and borne down on, to force the clinch above the rim. This operation should be repeated every few inches all the way around the rim, until the tire casing is entirely free on one side.

On account of its being necessary to work all around the rim, the operation of removing or replacing a tire is, of course, most conveniently performed when the vehicle is jacked up in such a manner as to leave the wheel free to turn about at the will of the operator.

When one side of the casing is removed, the valve stem should be pushed through the rim, the clips taken out, and the inner tube removed from the casing and repaired in the manner hereinafter described. Unless it is necessary for some other reason, both sides of the outer casing need not be removed. In case it should be entirely removed, however, the second part of the operation is similar to that of removing the first side, except that less care need be taken in using the lever, as there now is no danger of its injuring the inner tube.

Should the inner tube stick to the lining of the casing, it must be removed very carefully by a light, steady pull close to the point of adhesion. Otherwise, it is likely to tear.

If the exact location of the puncture is apparent through damage inflicted outside of the casing, or by the presence of the puncturing object, it is often unnecessary to remove the casing more than part way on one side. This permits the inner tube to be drawn into view.

If the puncture in the inner tube is hard to find, it can best be discovered by immersing it in water and pumping the tube up slightly. Bubbles of air rising through the water will then show any openings that may exist.

When enough water to permit total immersion of the tube is not available, a small quantity may be used to cover the tube, section by section, until its whole length has been tested.

Sometimes a leak can be detected by the hissing sound of air blowing out of the hole, but if this method is used, it is well also to examine the side of the tube directly opposite the principal puncture, since a nail, or any similar object, is quite likely to pass clear through the tube, making a large hole on one side and a small one on the other.

Another way of locating a very small puncture is to inflate the tube slightly and moisten all suspicious looking abrasions, one at a time. Any leak will show itself by small bubbles.

A hole in an inner tube being located, its repair consists in placing a patch of pure rubber over it. Sheet rubber for this purpose is sold by all tire manufacturers and bicycle and automobile supply houses. It can be cut into pieces to suit any size of puncture. Care always should be taken to use patches allowing a wide margin around any opening it is desired to repair.

The usual means of attaching a patch is rubber cement consisting of pure gum rubber dissolved in benzine or other volatile hydrocarbon. Before applying the adhesive, all dirt and moisture should carefully be removed, both from the patch and the por-

tion of the inner tube that is to be covered, and the contact surfaces should be well roughened by rubbing with a piece of sand paper or emery cloth, preferably the latter.

After the patch and tube are prepared, a thin, uniform coating of cement is applied to both surfaces and allowed to dry from ten to twenty-five minutes—until it is of a tacky consistency, indicated by a tendency to stick to the finger. This exactly correct condition can only be determined by experience, and the time taken for the cement to reach it varies in accordance with the consistency of the cement, the condition of the rubber, the dryness of the atmosphere, etc. Generally speaking, however, the cement should have entirely lost its original sliminess without having become too dry to be sticky.

The moment the cement is in the proper condition, the patch should be applied to the tube, and the two pressed very firmly together. A simple device for doing this, though a pair of strong hands are enough in an emergency, consists of two wooden blocks hinged together at one end and clamped at the other by a wing nut and bolt.

The commonest cause of patches not holding is careless cleaning and failure to cement the tube and patch clear to the edge of the latter. This results in loosening of one edge of the patch, ending in its complete detachment. Small vulcanizers and liquid vulcanizers are now on the market, and their use, if the instructions which accompany them are followed and proper materials used, insures a much better "job" in the way of patching than can be obtained by the process described.

An inner tube is comparatively light and occupies little space, so it always is well to carry an extra one or two, it being easier to substitute a new one than to repair a punctured one. The damaged tube can be then repaired under better conditions when more leisure is to be had, and held ready for use in the next emergency.

In carrying or storing inner tubes, it is essential that they be protected from heat and oil, either of which will quickly ruin anything made of good rubber. It is a good plan to keep extra inner tubes wrapped up in a linen cloth, or better still, in a rubber-covered waterproof canvas bag containing a quantity of powdered soapstone or French chalk.

REPLACING CLINCHER TIRES

Replacing a clincher tire is in most respects the reverse of removing it. It is necessary, however, that more care should be

exercised in this than in the other operation, because of the greater possibility of pinching the inner tube with the tire lever, between the clips, or between the clinches and the rim in such a manner as to tear or puncture it.

As the first step in replacing a tire with a protection strip, the strip must be placed evenly around the rim with the holes through it for the valve stem and the clips registering with the corresponding holes in the rim. Except for this detail, this tire is replaced in the same manner as others.

The air-tube should next be inflated just enough to cause it to assume a round shape.

The air-tube, the clinches, the inside of the outer casing, the rim, and the surface of the protection strip should next be dusted with powdered soapstone or French chalk. A can with a perforated top like a salt or pepper shaker is convenient for this. The powder helps the inner tube and casing to slide into their proper places when attached and inflated, and also has a tendency to keep the different parts from sticking together. Too much soapstone or chalk, especially the latter, in a tire is likely to form into small hard pellets, and do much harm.

With the inner tube in the outer casing, place the tire over the wheel, and insert the valve stem through the proper hole in the rim.

Now by means of one or two tire levers pry one clinch into place all the way around. Care should be taken in doing this not to stretch the casing more to one side of the wheel than the other.

Before the second clinch is placed in the rim, it becomes necessary to insert the clips, which must be carefully done, or the inner tube is likely to be pinched between the clip and the casing or between rim and the clinch. Pinching of the inner tube in any manner is certain to result in injury sooner or later, even though no immediate evidence of trouble appears.

To place the clips, thrust the lever clear under both sides of the casing, and raise it bodily, at the same time dropping the clip partly in position. As each clip is inserted, withdraw the lever sufficiently to allow the clinch on the side of the casing away from the operator to drop into place.

After the clips are in place, push them up, one at a time, to make sure that none of them is caught under the clinches or clips. The clips should then be felt of with the fingers before the second of the clinches is fixed in place, to make certain that the protecting leather or rubber heads of the clips are not kinked in any manner.

The washers and nuts can be next put on the clips, the nuts being caught just enough to hold them in place. Many clip stems have a short portion at the end threaded—with a middle section plain—to simplify this partial fixing of the nuts.

The second clinch of the casing is usually worked into place by means of two levers, the utmost care being used not to cut or pinch the inner tube. To avoid such a mishap, it is best to insert the first lever near a clip, first pushing the inner tube well up and out of the way by means of the clip. The other lever can be then placed a little distance to one side, and in this way, by progressively advancing the levers around to the rim a distance equal to about one-third of the tire's diameter each time, the tire is properly placed, the clinches dropping into position and the levers being withdrawn as the work is done.

In working past the air valve, it is important to see that the inner tube is not pinched between it and the casing. It also is well to place the last bit of cover immediately opposite a clip, as this keeps the tube up in the cover, preventing it from being nipped as the edge finally snaps into place.

As a final test, to make sure that the air-tube is not pinched under the clinches, the casing can be pressed back with the thumbs where it fits into the rim, both hands assisting the process by holding the top of the tire back. As the clinch slides back toward the middle of the rim, it can be at the same time slightly lifted to see if the inner tube shows under it. If this operation is continued all around the tire, especially on the side last applied, and the inner tube fails to show at any point, it may be concluded that it is rightly placed. Should the inner tube show at any point, however, the lever must be again brought into play and the tube carefully worked away from the edge of the casing.

Before inflating the tire, each clip and the valve stem should be tested by having its stem pushed back through the rim. If any fail to lift up freely, it is likely that they are held down by a pinched inner tube.

When the clinch at any point proves very difficult to work into place, the chances are that it is over instead of under the clip head, in which case it should be removed, and replaced correctly.

When everything seems to be in shape—the outer casing, the inner tube, the clinches, and the rim being in place, the clip nuts should be tightened up and the tire inflated to a pressure ranging from 50 to 100 pounds to the square inch, according to the size of the tire and the weight it has to carry. After the tire is inflated it will be found that the clip nuts need slight re-tightening.

Some of the pumps now used for inflating motor vehicle tires are fitted with a gauge, by which the pressure during inflation is clearly indicated. In the absence of a gauge, it is sufficient to test the tire pressure with the hand, or by the amount of flattening the weight of the vehicle occasions.

As a general rule, and despite the persistent contrary belief of many who should know better, a motor vehicle tire should be kept pumped hard rather than soft to give the best service. A soft tire may run easy and will reduce danger of skidding, but it will rapidly wear out.

In manipulating a tire of the sort which has a flap instead of a protection strip, the inner tube should contain very little air when placed in the casing. To empty it thus completely, open the valve and roll up the tube.

The valve stem of a tire of this sort passes through a hole in the flap as well as through the one in the rim, and the inner tube must be kept behind the flap at all times while the casing is going on the rim. The flap also must be kept out of the way, to avoid its catching under the clips or clinches.

An inner tube that has been immersed in water positively should be thoroughly dry before being replaced on the wheel; otherwise it may cause the lining of the casing to rot. This furnishes an additional reason for always using a spare tube in preference to replacing one that has been just repaired.

A mistake often made by the careless or unthinking is the ignorant use of clips or rims of one make with tires of another. This practice cannot be too strongly condemned, because it is almost certain to result in trouble. Different tire makers do not employ the same clips and rims, though there is a commendable tendency toward standardization of these parts, and until standardization has become general, interchanging parts of one tire with those of another is simply courting disaster. If by any chance a motorist finds it convenient to make a substitution of clips or rims, he should be sure to make inquiries that will conclusively determine whether the ones he proposes to use are really correct form. The effect of using clips of even a slightly wrong profile is very bad.

Mechanically Fastened Tires. The advantages of mechanical fastenings are several. Most important, doubtless, are the security of attachment and the readiness of removal; but it is also a fact that a mechanically fastened tire is not so subject to injury from running deflated as is a tire held in place by air pressure.

Repairs to mechanically fastened tires are little different from

those made to clincher tires. Practically the only differences in handling the two types relate to removing the tire and reaching the injury. When a mechanically fastened tire is off, it is repaired by about the same methods that apply to the clincher pattern.

The most important tendencies in modern pneumatic tire design are toward mechanical attachments, complete waterproofing —the use of rubber to cover every portion of fabric; the placing of air chambers well above wheel rims and the employment of designs facilitating the inexpensive renewal of treads.

Any puncture is serious enough to render a repair of the outer cover more or less advisable. Generally it is best to repair a cut in the outer cover at once, regardless of whether or not the inner tube happens to be penetrated.

Wear on Tires. Wear of a tire is of two sorts—one the slow abrasion, or grinding away of its surface, averaging only about 1/5,000,000 inch of tread thickness to each revolution of the wheel; and the other the cutting and clipping away of its material by sharp rocks, broken glass, nails, etc. Either form of wear is unavoidable, but with the latter the damage can be greatly minimized by cleaning out all small lacerations with benzine and filling them with a solution such as is used in the patching of inner tubes. This is especially advisable if the cuts are so deep or extensive as to expose the fabric, or to loosen small pieces of rubber.

Any cut that reaches the fabric and is left unattended to will permit water and grit to work gradually along the layers of cloth, rotting and grinding it away. The progress of this action is marked by the formation of curious appearing blisters and lumps, in some cases soft and loose and in others filled with hard concretions of sand and dirt. The orignal puncture in the meantime enlarges to a point where the weakened fabric around it can no longer withstand the pressure of the inner tube, which is finally forced through the casing and bursts with a loud report—constituting a "blow-out."

A blistered tire hardly can be repaired outside of a tire factory, the vulcanizing on of a new tread being practically its only salvation. Frequently it is necessary even to add pieces of fabric to reinforce the weakened places in the fabric originally incorporated in the tire when it was manufactured.

When a tire casing is badly cut and after the inner tube has been repaired or a new one fitted, it usually is possible to run a good many miles without further trouble by using a repair sleeve, a shield laced around the outside of the tire, over the in-

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Sometimes a mudguard support or a driving chain will wear a tire badly at the sides, if it run deflated. This is because a flattened tire occupies considerably more lateral space than does one that is pumped tight. A tire that is run deflated is also likely to be cut by the rim, and damaged by the sharp creases made in the casing by the flattening.

Driving at high speed around a curve imposes tremendous stresses on any tire, tending to tear it off the rim. The centrifugal force due to the momentum of the vehicle in making a turn increases in geometrical progression as the speed is increased—a speed twice as great imposing stresses four times as great, and so on. Consequently a careful driver, desirous of saving his tires, never rounds curves too sharply.

Another thing that injures tires when going around curves is the fact that, through the centrifugal force, a great excess of the weight is borne solely by two outer wheels, the tires of which are proportionally over-taxed.

High speed is of itself a serious factor in tire deterioration, a tire being worn much more in going sixty miles in two hours, than it is in going sixty miles in three hours. The disproportionate severity of high speed thus has a serious effect upon tire mileage.

Tire Inflation Pressure. The following general advice in regard to the care of pneumatic tires and to their deflation in particular is given by one of the largest American tire makers.

"If tire users would be as particular in caring for their tires as the manufacturers are in making them, there would probably be few tire troubles. Like everything else, automobile tires must be properly used in order to give the maximum amount of service. For instance, every motorist knows that rim-cutting is one of the most frequent, as well as one of the most disastrous, of tire troubles; but apparently all motorists do not know that in four cases out of five rim-cutting is directly traceable to inadequate inflation of the tires.

"'Hinging' is decidedly greater (and naturally so) with an inadequately inflated tire than it is with a properly inflated one, and it is this constant bending that plays havoc with the walls of the tire. The difference between sixty-five and eighty-five pounds of pressure may not seem great, but in a large number of cases it is the difference between numerous troubles and good tire service.

"The purchase of a pressure register will prove to be one of the most economical purchases that a motorist can make. It will enable him to know to a certainty whether his tires are being kept in a safe condition.

CHAPTER III.

GASOLINE ENGINES

The term "*gasoline engine*" has come to be so widely applied in common speech to that type of prime mover most used for propelling automobiles and similar motor vehicles, simply because gasoline is at present the fuel oftenest used in such engines. As a matter of fact, however, there are many other fuels capable of taking the place of gasoline, and it is not unlikely that in the near future some of these may prove even more suitable and less expensive. Consequently, the term "gasoline," as applied to motor vehicles and their engines, may in time become a misnomer, but since it at present is firmly intrenched in the language, it will be employed herein in the commonly-accepted sense.

"Gasoline engines" are more correctly and not infrequently referred to as "*internal combustion*" or "*hydrocarbon*" motors, because they invariably utilize a liquid or gaseous *hydrocarbon* as their source of power; this liquid or gaseous hydrocarbon, mixed with air, being burned directly inside the engine cylinder.

The gasoline engine is lighter for a given power output than any other self-contained prime mover. Some steam engines and electric motors alone may be lighter than gasoline engines of equal power, but steam engines require boilers to supply the steam and electric motors must be furnished with current from batteries or other external source, whereas a gasoline engine embodies within itself, as explained later, all the elements of a complete power plant.

While the considerable complication of accessory detail that ordinarily is necessary to the satisfactory application of a gasoline engine to practical purposes has doubtless a confusing effect upon the lay mind, the essential principles of gasoline-engine operation are exceedingly simple and easy to comprehend.

Every gasoline engine is composed of certain fundamental elements, which only seem complex as they may be combined

with intricate and somewhat perplexing auxiliary devices. Therefore it will be the object herein to give first consideration to the basic elements of construction, after which subordinate details will be treated approximately, in the order of their relative importance.

Cylinder and Piston. The most important parts of a gasoline engine are the *cylinder* and the *piston*. The first of these is a tight cylindrical casing of metal, smoothly machined and highly finished within, and closed at one end by a cylinder head. The piston is practically a close-fitting metal plug, made to slide to and fro within the cylinder. The two, assembled as shown in Fig. 3, in which *c c* represents the cylinder and *p* the piston, constitute the simplest conceivable form of a reciprocating engine.

Fig. 3

Fig. 4

The power of most gasoline engines is developed by the "explosion," or rapid combustion with consequent expansion, of an inflammable gas within the space *e*, Fig. 4, above the piston. This has a tendency to drive the piston out of the cylinder with great force, unless some provision is made to control its action, and at the same time to convert the energy of its movement into available form.

For most power purposes, particularly in the case of motor vehicles, it is desirable to have power developed in the form of a continuous rotary motion, as this is the form in which the power is applied to the onward movement of the vehicle—that is to say, to the rotating of the driving-wheels. Consequently it is necessary, by some means, to cause the to-and-fro movement to communicate a rotary motion to some other element of the mechanism.

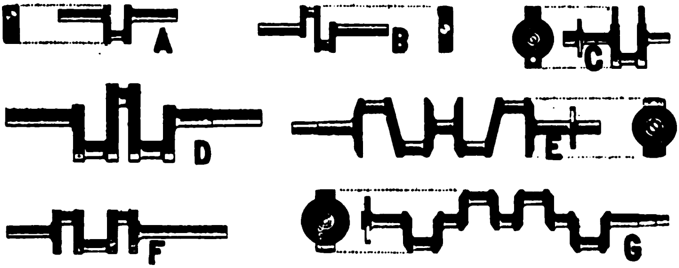


FIG. 5

The transformation of reciprocating into rotary motion is, in a gasoline or steam engine, usually effected by the use of a *crank* and a *connecting-rod*.

A *crank* may be defined as an offset portion of a shaft, carrying an independent bearing or its equivalent, which must move in a circle about the shaft's center of rotation.

Forms of cranks, such as are commonly used in actual engine construction, are shown at *A*, *B*, *C*, *D*, *E*, *F* and *G*, Fig 5.

A *connecting-rod*, in its simplest form, is a short and very stout

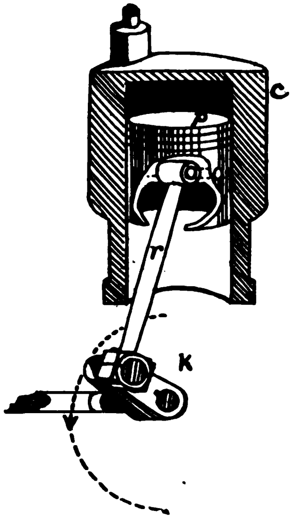


FIG. 6

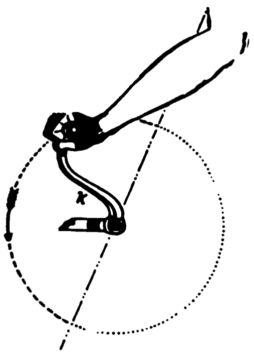


FIG. 7

bar, made to connect at one end with a crank, and at the other with a piston. Thus, a cylinder *c*, piston *p*, connecting rod *r*, and crank *k*, arranged as in Fig. 6, are equivalent to the arm and crank shown in Fig. 7. It is evident that any pressure upon the head of the piston *p*—from an expanding gas—acts like the pressure of the arm in Fig. 7, the tendency in both cases being to force the crank *r* around in the direction indicated by the arrow and the dotted line. In this way, a partial rotation of the shaft is easily effected.

FLYWHEELS

To make this rotation continuous, it is necessary either to employ a flywheel or a number of cranks and connecting rods set at different angles, or both, so that at the moment any given connecting-rod is in the "dead center" positions, in which it is obvious that neither pushing nor pulling on the connecting rod can turn the cranks, there will always be some other just coming into action, or a flywheel carrying on the rotation. The tendency of a flywheel is always to continue to rotate for some time after it has been given an initial impulse, and a motor fitted with a properly designed flywheel, though it have but one cylinder, and consequently intermittent power impulses, will continue to maintain its shaft in rotation, because the momentum of the flywheel is sufficient to carry the crank past the dead centers and the idle portions of the strokes.

The more cylinders there are in a reciprocating engine, the more impulses there are to each revolution, provided the cranks are spaced in a proper manner. There is a limit, however, to the number of cylinders which it is practical to use.

Since the action of a gasoline engine depends upon the combustion within it of a gaseous fuel, it is evident that means must be provided for introducing fresh charges and for disposing of those that have been burned. This requirement is met by the use of valves, which open and close ports opening into the cylinder and which are so controlled by suitable mechanisms that their movements are so timed as to insure regular and efficient operation.

To use gasoline engines successfully, some provision must be made for keeping their parts cool. Considerable heat is developed if the fuel is consumed in the engine, and, were there not some means of cooling, the cylinder wall, the valve stems, and even the piston would soon become so hot as to work certain destruction to the lubricant employed between the different moving parts, and probable injury to the metal itself.

Explosive Mixtures. An "*explosive-mixture*" is a mixture of air and vaporized gasoline or other liquid hydrocarbon, or of air and any combustible gas. Such a mixture burns with explosive violence when ignited, because of the peculiar character of the chemical union of the elements. The burning of an explosive mixture tends, by the great heat generated, to expand the gases, but as they are confined in small space their tendency to expand simply results in great pressure being exerted upon the walls of the cylinder and the head of the piston.

The expansion of gas in a gasoline-engine cylinder is not due, as in the case of explosives, to an increase in space required as the result of a chemical combination, but simply to the ordinary

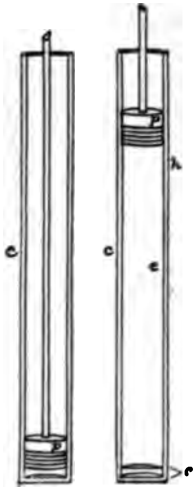


FIG. 8

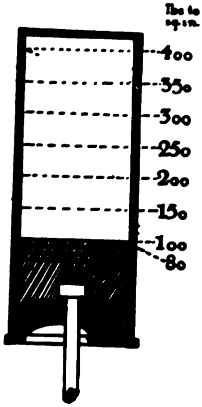


FIG. 9

expansion that takes place in any gas when it is heated. Therefore, neither expansion nor pressure persist after the ignited mixture has cooled. For instance, if in Fig. 8 the gas under the piston *p* is exploded by ignition, and the cylinder *c* is sufficiently long, the piston will rise to a point, *h*, in Fig. 8, determined by the original quantity of gas, its composition, and the heat generated by its combustion. Then, if the gases are permitted to cool to their original temperature, they will return to their original volume, or slightly less, permitting the piston to drop back to approximately its original position *o*, Fig. 8.

The temperature that results from the ignition of the different gaseous mixtures used in internal combustion engines varies widely, but may run as high as 3,000° Fahr., or even more. It is this tremendous rise above atmospheric temperature that produces a proportionate increase in volume, or, if the gas is confined, in pressure. Consequently the piston of an engine, located in the cylinder in a manner to be acted upon by gases suddenly heated by their own combustion, will evidently move with a force that can be turned into an amount of useful work.

The original pressure that immediately follows ignition of the mixture in a gasoline engine is ordinarily from 300 to 400 pounds to the square inch, but rapidly drops to as low as 60 or 80 pounds to the square inch as the outward movement of the piston permits the gas to expand, as illustrated in Fig. 9.

The power of an engine is determined by the average pressure to the square inch maintained on the piston throughout the stroke, by the number of square inches the top of the piston presents to the expanding gas, by the distance the piston travels during each stroke, and by the number of power strokes it makes within a given time. From this theoretical power output, must be subtracted the losses due to the negative work of compression, to the friction of different portions of the mechanism, and to other causes.

In the practical use of liquid hydrocarbons in gasoline engines, it is necessary to have means for vaporizing and mixing them with air, and means for igniting them. Preparation of the gaseous fuel is generally accomplished by a device called a *carbureter*. Ignition involves the use of an *ignition system*, the most-used type of which consists of devices for producing within the cylinder of the engine an electric spark of sufficient strength to fire the gases. Other means are sometimes used, especially in stationary practice.

Cycles of Gasoline-Engine Operation. Clearly it is necessary in a gasoline engine of the reciprocating form—that is, in an engine making use of a cylinder having a piston moving to and fro within it—to provide that the successive operations of introducing the charge, of compressing it before ignition, of utilizing the force of its expansion, and of exhausting it, shall occur in their correct sequence. These various operations are differently performed in engines of different makes—even to the point of some of them being in a degree dispensed with—and often are distributed differently through the successive strokes of one or more pistons.

Four-Cycle Gasoline Engines. In the type of gasoline engine

most used, the four actions of *suction, compression, explosion* and *exhaust* are performed in four successive strokes of one piston, one action to each stroke, after which the same *cycle of operation* is repeated indefinitely. This cycle of operation is known as the "Beau de Rochas" or "Otto," after the man who first proposed it, and the man who first realized it in a working mechanism, respectively. In common nomenclature, an engine employing it is referred to as a "four-cycle engine."

TYPICAL FOUR-CYCLE ENGINES

The principle of a four-cycle engine is illustrated in Fig. 10, in which *A, B, C* and *D* show a cylinder with the piston in four successive positions—at the commencement of a suction stroke, the commencement of a compression stroke, the commencement of

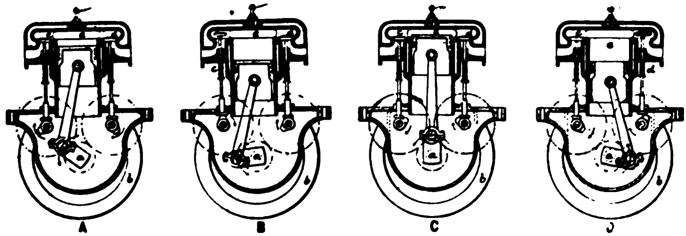


FIG. 10

a power, or explosion, stroke, and the commencement of an exhaust stroke, respectively.

It will be noted that the commencement of a suction stroke corresponds to the end of an exhaust stroke, the commencement of a compression stroke to the end of a suction stroke, the commencement of an explosion stroke to the end of a compression stroke, and the commencement of an exhaust stroke to the end of an explosion stroke.

Upon reference to the various positions of the crank and flywheel in Fig. 10, it is evident that two revolutions of the engine shaft, *a a a a*, occur during the completion of the four strokes of the cycle. It will also be observed that the movement of the piston is a simple and continuous to-and-fro motion—it moving once inward and once outward during each revolution—and that the suction strokes and the explosion strokes are exactly similar—always outward—while the compression strokes and the exhaust strokes also correspond, but are always inward. That a given out-

ward stroke is a suction or explosion stroke is determined not by any difference in the movement of the piston, but by the operation of the valve and ignition mechanisms. The same holds true of inward strokes, which are compression and exhaust strokes alternately.

Starting with the piston and cylinder of a four-cycle engine as shown at *A*, Fig. 10, with the flywheel *b* rotating in the direction of the arrows on account of its momentum, a charge of fuel and air is drawn into the cylinder through the *inlet valve c*, from a pipe that communicates with the carbureter or other source of fuel supply, the *exhaust valve d* being closed meantime. This induction of a charge continues until the piston is at the end of the stroke under way in *B*, Fig. 10.

The rotation of the shaft still continuing because of the flywheel's momentum, the piston returns to its original position; and, inlet and exhaust valves both closed, the charge, which at first filled the whole cylinder, is compressed into the space above the limit of the piston's inward stroke—the *compression space e e*, in *A* and *C*, Fig. 10.

The explosion stroke, the commencement of which is shown at *C*, Fig. 10, is caused by the ignition of the compressed charge, which in expanding drives the piston down with great force, the impulse thus given being powerful enough, not merely to keep the motor running until the next power stroke, but to do the work demanded of the engine besides. The inlet and exhaust valves remain closed during the power stroke.

During the exhaust stroke, as in *D*, Fig. 10, the exhaust valve *d* opens, permitting the discharge of the burnt gases directly or indirectly into the atmosphere. The power to keep the engine moving during the exhaust stroke is again derived from the momentum of the flywheel, as in the case of the suction and compression strokes.

When an exhaust stroke is completed, a suction stroke immediately follows, and the cycle of operation is thus repeated over and over.

Though the foregoing type of engine affords but one power impulse for each four strokes, or two revolutions, it is far more generally used than others, because of the perfect manner in which it performs the several operations necessary to the most convenient and efficient utilization of an explosive mixture.

The exhaust of a four-cycle engine is never complete, there being always a proportion of the burnt gases retained in the compression space, to dilute and weaken the incoming mixture.

To minimize this evil, and for other reasons, compression spaces are usually as small in proportion to the maximum cylinder contents as possible. But as a reduction in compression space results in an increase of compression pressure a limit is reached that cannot be exceeded without preignition, from the heat of the compression. A compression space of about one-fifth of the cylinder capacity, corresponding to a pressure of about 90 pounds to the square inch with full charges, is about the average with the best motor-vehicle engines. There is a tendency, however, towards the use of compressions ranging even as high as 150 pounds to the square inch, and with certain fuels such high compressions may become general. With fuels not easily ignited, such as alcohol and some others, very much higher compression can be used than is practicable with gasoline, for preignition will not occur at as low temperature with the two first named as with the latter.

Within reasonable limits, there is no question but that the higher the compression, the higher the economy to be obtained from an engine.

High compression reduces heat losses, conduces to complete and satisfactory ignition of the fuel—because of the heat of compression—and reduces the admixture of burnt gases with the fresh charges.

The actual pressure that can be obtained in a gasoline engine is always considerably lower than the theoretical pressure, as calculated from the ratio that the compression space bears to the space of the whole cylinder. This is owing to slight and unavoidable leakages past the piston and valves, and to the fact that an engine rarely secures a full charge at atmospheric pressure during the suction stroke, especially if the engine is running at high speed. A calculated pressure of as much as 105 pounds to the square inch may be quite necessary to insure an actual compression of 80 pounds to the square inch.

It must be remembered that, as ordinary air is normally under a pressure of 14.7 pounds to the square inch, there is to be taken into account a corresponding difference between *absolute* and *gauge* pressure.

Theoretically, for the best results, a four-cycle engine requires a charge as cold as possible, consistent with perfect vaporization of the fuel, compression of the charge without altering its temperature, combustion producing a high temperature and accompanied by expansion to atmospheric pressure without lowering of temperature, and absolutely complete exhaust. These contrary

requirements are of course impossible to meet fully in practice, but the best engines are those most nearly approximating them.

The advantage of a cold charge, speaking comparatively, is that the greatest possible amount of mixture is thus introduced into a cylinder, for if a given quantity of gas be heated, less of it will fill a given space than if it were cold.

Though a great majority of all four-cycle engines are of the general type just described, there is a variety of other constructions. Most of these have been inspired by a desire to do away with various of the well-understood objections to the more common types, and some of them have met with considerable success.

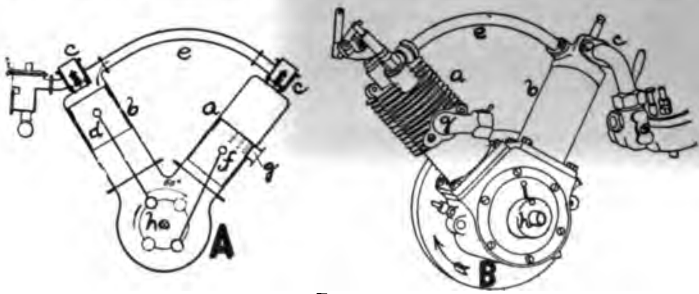


FIG. 11

Two-Cycle Gasoline Engines. A two-cycle gasoline engine is one in which the charge is both introduced into and fired in the cylinder during one stroke, and exhausted during the next, the cycle thus occupying but two strokes, and there being one power impulse to each revolution of the engine shaft. The four essential operations, however, of compression, suction, explosion, and exhaust, are none the less performed, the difference between four-cycle and two-cycle motors being not so much a difference in the operations performed as it is a difference in the manner of performing them.

DOUBLE-CYLINDER TWO-CYCLE ENGINES

Probably the type of two-cycle engine easiest to understand is the unusual one illustrated at *A* and *B*, Fig. 11, in which *a* is a power cylinder and *b* a pumping cylinder. The fresh charge is first drawn into the cylinder *b* through the valve *c*, by the downward stroke of the piston *d*, and then delivered into the cylinder *a*, through the pipe *e*. The charge is fired as it enters *a*, thus

communicating a power-impulse to the piston *f*, as it moves on its downward stroke. When this piston reaches the limit of its downward travel, it uncovers the port *g*, in the wall of the cylinder *a*, and permits a major portion of the burnt charge to be exhausted, while a fresh charge from *b* is already on its way through *e*. With this engine, it is evident that there is an impulse on the shaft *h* once in each revolution, the cylinder *b* alternately aspiring and compressing a charge, and the cylinder *a* alternately firing and exhausting one.

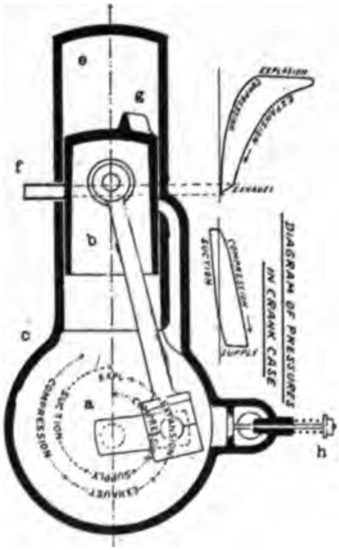


FIG. 12

TYPICAL TWO-CYCLE ENGINE

A common form of the two-cycle engine is the "two-port" engine, shown at *A* and *B*, Fig. 12, in which all the operations of the cycle are performed in one cylinder. In this engine the crank-chamber space *a*, below the piston *b*, is completely enclosed by the crank case *c*, and performs substantially the same pumping functions as are performed by the auxiliary cylinder *b* in Fig. 11. The bypass *d*, which at a certain period of the stroke connects the upper portion of the cylinder with the crank-chamber, performs

practically the same functions as the pipe *e* in Fig. 11. Although the cycle is less easy to follow in this engine, it is fundamentally the same as that in Fig. 11, the sequence of four operations being performed above and below one piston, instead of wholly above two pistons.

In Fig. 12, the piston is half way on a downward or power stroke, the charge in the combustion space *e* having been just ignited. At the same time, a charge previously introduced into the crank chamber *a* is compressed by the downward movement of the piston. When the top of the piston has descended enough to uncover the port *f*, near the lower extreme of its motion, the burnt gases escape through this.

A slight further descent of the piston, *b*, Fig. 12, uncovers the bypass *d*, connecting the combustion space *e* with the crank chamber *a*. The charge in the crank chamber being by this time considerably compressed, it rushes through *d*, filling the combustion space, and helping to force the exhaust gases out through *f*. A deflecting plate, *g*, turns the incoming charge towards the top of the cylinder, thus preventing it from blowing horizontally across the cylinder and out through the exhaust port *f*. As the piston now rises, it first closes *d* and then *f*. Continuing upwards, it compresses the charge above it, at the same time drawing more gas into the crank chamber through the inlet or check valve *h*. When the position of starting is reached again, the charge is fired and the cycle of operations repeated.

Almost all two-cycle engines are constructed about as the one just described, differences being usually in details only.

In the "three-port" two-cycle engine, now displacing the two-port type, a crank case port *i*, Fig. 13, is substituted for the inlet valve *h*, Fig. 13. By this construction, moving valves are entirely avoided, the piston and the ports in the cylinder wall taking their place. Moreover, with the form illustrated in Fig. 13, it is claimed that considerably more power is secured than is developed by an engine of the type shown in Fig. 12.

A prominent maker of two-cycle engines said this about them: "Some of the numerous advantages of the latest and most improved type of two-cycle engine over all other types, especially for automobile work, are as follows: Its ability with one cylinder to give an impulse to the crankshaft at every revolution, with but three moving or working engine parts, against the thirty or more moving and working parts in a four-cycle, two-cylinder engine, necessary to obtain ample power at all speeds, with the least number of parts. The small, noisy, delicate, wearable, adjustable and

adjustable parts only are the parts retained. The engines are silent, there being no noise except the exhaust. Due to the simplicity and strength of working parts great durability and reliability are obtained with freedom from breakage and replacements."

Multi-cylinder Gasoline Engines. The rapidity with which the power strokes follow one another in the cylinder of a gasoline engine, at intervals of from less than 1 second to 1/25 of a second, makes it impracticable to keep a cylinder wall hot enough to

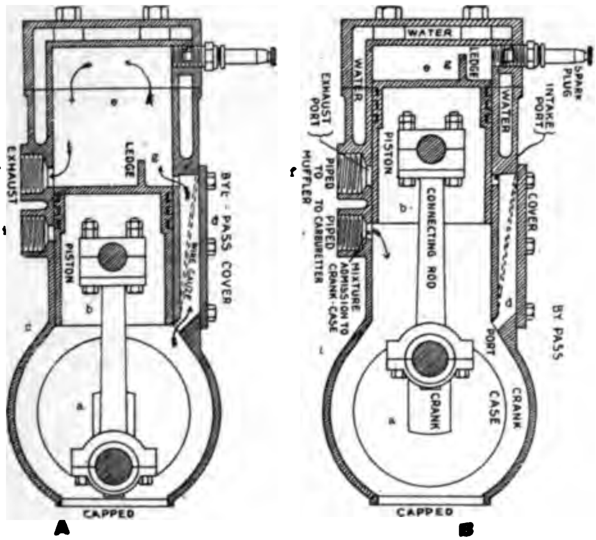


FIG. 13

prevent its abstracting heat from the exploding charge, because a hot wall would heat the incoming charge too greatly. Conversely, cooling the walls of a cylinder unduly wastes the heat of the exploding gases. Therefore, since the area of any cylinder wall increases only as the square of the cylinder's size, while its capacity and power output increase as the cube of its size, it follows that a large single-cylinder engine is more economical than one of the same power with a number of small cylinders. Consequently, the use of one cylinder is theoretically most economical. In practice, however, allowance is not always made for this fact,

because there are other matters even more important than mere high efficiency, that cannot be neglected.

Chief among these is the desirability of frequent power impulses—thus permitting of a smaller flywheel, while at the same time maintaining the rotation of the crank-shaft. In a multi-cylinder engine, frequency of impulse is usually attained by so spacing the operations in the cylinders that a power impulse is occurring behind one piston while the other pistons are on idle strokes.

Another object in multiplying cylinders is to reduce the vibration and jar that is set up whenever there is a rapid, periodic change in the direction of a moving part—as is the case with an engine piston.

Vibration is due to the tendency of every mechanism, contend-

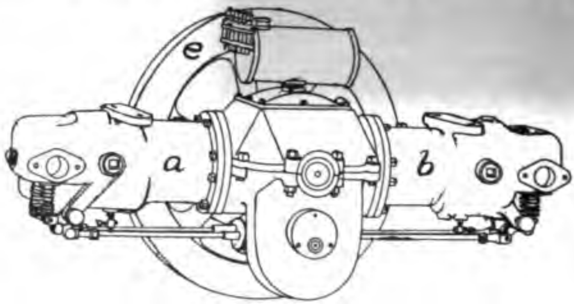


Fig. 14

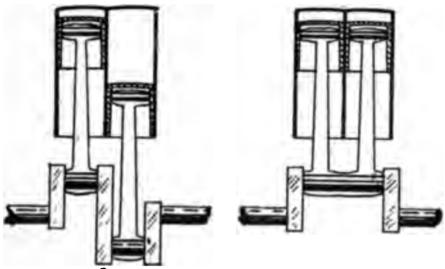
ing against the inertia and momentum of rapidly moving parts, to maintain its center of gravity immovable at a fixed point by the potential movement of such fixed part at such time and to such extent as will compensate for every change in position of the part or parts that cause the disturbance of the center of gravity. Therefore, if each moving part in an engine is balanced by a similar part moving always in an opposite direction, vibration is largely eliminated. This is the case to an extent in a multi-cylinder engine, in which one piston moves one way while the other moves in the opposite direction, etc.

TWO-CYLINDER ENGINES

Two-cylinder gasoline engines are built in several forms, the following being the most important:

Horizontal-opposed engines, consisting of two cylinders, *a* and *b*, arranged as in Fig. 14, the two pistons within which alternately approach and recede, from each other, constitute one of the best, known and most widely employed types in motor-vehicle construction. In engines of this type, the explosions are usually timed to occur alternately, the flywheel *e* maintaining the rotation between impulses. The cranks are spaced one hundred and eighty degrees from each other, so there is always a very perfect balance in moving parts, power impulses, and idle strokes—similar actions always occurring in each cylinder at the same moment, but in opposite directions.

Engines of the horizontal-opposed type are occasionally designed with both connecting rods on the same shaft, or with the explosions simultaneous in the two cylinders. A little con-



A FIG. 15 B

sideration, however, makes it evident that neither of these cycles of operation can be as satisfactory as that already described.

Vertical two-cylinder engines are built in either of the forms shown at *A* and *B*, Fig. 15. In *A* the connecting rods work on cranks 180° apart, necessarily resulting in two explosion strokes in succession followed by two idle strokes in succession—an obviously irregular cycle. In other words, the explosions first occur on succeeding strokes, but continue with two idle strokes between them. This is made clear by the following table, which shows what occurs during the four strokes of the cycle of operation in each cylinder.

	IN 1ST CYLINDER.	IN 2D CYLINDER.	
1st Stroke	Explosion	Compression	*Power stroke*
2d Stroke	Exhaust	Explosion	*Power stroke*
3d Stroke	Suction	Exhaust	*No power stroke*
4th Stroke	Compression	Suction	*No power stroke*

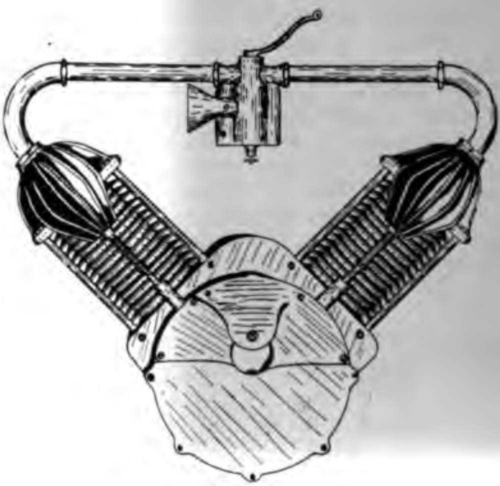


FIG. 16

The fact that the moving parts—the pistons and connecting rods—balance each other largely compensates for the irregular power development in this type of engine. Some endwise vibration, however, results from the rising of a piston at one end of the engine while that at the other end falls. With the engine shown at *B*, Fig. 15, regular alternation in power and idle strokes is secured at a sacrifice of the mechanical balance of parts. The following table shows the sequence of strokes:

	IN 1ST CYLINDER.	IN 2D CYLINDER	
1st Stroke	Explosion	Suction	*Power stroke*
2d Stroke	Exhaust	Compression	*No power stroke*
3d Stroke	Suction	Explosion	*Power stroke*
4th Stroke	Compression	Exhaust	*No power stroke*

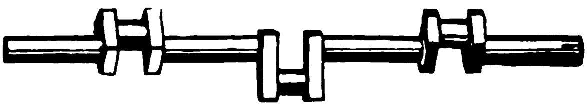
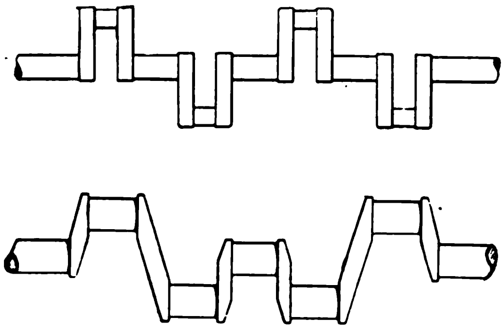


FIG. 17

The *V-shaped two-cylinder engine* shown in Fig. 16, effects a compromise between the advantages of horizontal-opposed and twin-cylinder vertical engines. In such engines, with cranks 70° to 90° apart, a perfect balance of power impulses is afforded, exactly corresponding to that given in the table immediately preceding, and an approximate balance of moving parts.

THREE-CYLINDER ENGINES

Vertical or horizontal three-cylinder engines, especially the former, are fairly common. They assure better balance, both of moving parts and impulses, than is possible with two-cylinder vertical engines, while at the same time they avoid much of the complication that attaches to engines having more cylinders. Practically all three-cylinder engines have the cranks set one-third of a revolution—120°—apart, thus making a power stroke regularly



FIGS. 18 AND 19

every two-thirds of a revolution. At the same time, the moving parts are in practically perfect balance—the momentum and relation of each moving part being such that it is at all times counterbalanced by other moving parts. The crank shaft of a three-cylinder engine is shown in Fig. 17, the crank-shaft being the principal detail that varies in engines otherwise to be distinguished only by the number of their cylinders.

A gasoline engine with four cylinders is by many authorities considered to be the most desirable type for motor vehicles, striking a mean between the poor balance and irregular power impulses of engines with less cylinders and the excessive complication of engines with more cylinders. With four cylinders, because of there

being one power stroke in every four in the usual four-cycle, it possible to have one power stroke to every stroke of the complet engine, one cylinder always containing an exploding charge whi the others are passing through the various idle strokes of tl cycle.

Four-cylinder engines are built with crank-shafts arrange either as in Figs. 18 or 19. The latter is preferred because does away with the endwise vibration otherwise likely to be ver marked. With the crank-shaft arranged as in Fig. 18, the arrang ment of the cycles in the different cylinders is as follows:

	IN 1ST CYLINDER	IN 2D CYLINDER	IN 3D CYLINDER	IN 4TH CYLINDER
1st Stroke	Explosion	Exhaust	Suction	Compressio
2d Stroke	Exhaust	Suction	Compression	Explosion
3d Stroke	Suction	Compression	Explosion	Exhaust
4th Stroke	Compression	Explosion	Exhaust	Suction

In this arrangement it will be noticed that an explosion in or cylinder is opposed to a compression in an adjoining cylinder du ing three strokes of the engine, and that then explosion in an en cylinder is opposed to a compression in the cylinder farthest awa from it.

This irregular moving about of the points at which the pow is developed and the greatest power expended—explosion an compression respectively—results in a very unequal balance an in a sort of endwise "rocking" of the engine.

With the arrangement shown in Fig. 19, however, the cyc of operations in the different cylinders is more symmetrical, bein that indicated in the following table:

	IN 1ST CYLINDER	IN 2D CYLINDER	IN 3D CYLINDER	IN 4TH CYLINDER
1st Stroke	Exhaust	Explosion	Suction	Suction
2d Stroke	Suction	Exhaust	Compression	Exhaust
3d Stroke	Compression	Suction	Explosion	Explosion
4th Stroke	Explosion	Compression	Exhaust	Compressio

With this arrangement it will be noticed that the opposition explosion and compression occurs in cylinders adjoining and i cylinders separated by one between them, alternately.

So perfect is the balance and so continuous the development power in a well-designed four-cylinder four-cycle engine th engines of this type, fitted with compensating carbureters and ef cient means of throttling, are made to run anywhere from as lo

as 80 to as high as 1,800 revolutions a minute, 1,000 revolutions probably being the speed of highest efficiency.

FIVE-CYLINDER ENGINES

Five-cylinder engines are uncommon, but have been experimented with by a few manufacturers who claim that the type possesses considerable merit. In at least one instance, an engine with five cylinders has been proved to give good results.

SIX-CYLINDER ENGINES

Engines with six cylinders are successfully used in several well-known cars, and also in motor boats. The advantages claimed for them are a very complete immunity from vibration, together

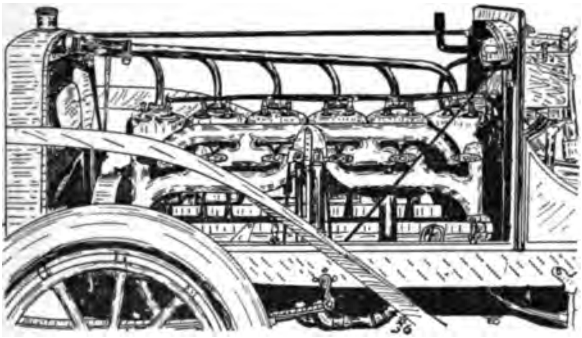


FIG. 20

with a still evener development of power than is possible with four-cylinder engines. In a four-cylinder engine, a new power stroke begins just as the one preceding ends; in a six-cylinder engine, the power strokes overlap, one commencing before the preceding one is completed. A typical six-cylinder engine is pictured in Fig. 20.

A writer in MoToR had the following to say regarding six-cylinder motors:

"From a purely academic point of view, six cylinders are very superior to four for automobile service because of the perfect balance and greater continuity of turning effort which are inherent in the former type. Practical engineering, however, in general somewhat modifies these advantages, or, more properly speaking, heightens the significance of points which do not enter into

academic considerations. Thus: Supposing two engines, one of each type of equal power at the same speed, which presupposes equal strokes, it is readily seen that the weights of the reciprocating parts cannot be much less in the six than those of similar parts in the four-cylinder engine. In practice, these weights are further reduced through shortening the stroke of the six, which necessitates a higher speed of rotation for equal piston speeds. Higher rotative speed makes for increased fuel economy, but also makes for greater wear and tear on the engine parts, makes a lower gearing ratio necessary, and increases the difficulties and losses in gas distribution to a greater extent in the six than in the four. All the foregoing drawbacks are, however, amenable to elimination through careful and exact designing; and thus the better balance and greater flexibility of the six may be preserved with but little modification from that indicated in the opening of this paragraph.

"While these very considerable advantages are attained, they, and those others directly depending upon them, are unattended by others of importance, such as: Increased thermal or mechanical efficiency; less engine weight; simpler and more efficient ignition, carburetion, and cooling systems; and simpler engine control. However, with six cylinders, engine control is largely substituted for gear control, and thus the car is capable of being handled more easily and with less effort. It has been repeatedly proven that six cylinders do not necessarily make a more speedy car, but add rather to its comfort and luxuriousness at reasonable speeds. The life of a six-cylinder car, equal in design, material and workmanship with a four, should be longer if proper attention is given it and the greater flexibility of the engine is not overworked in the car's operation.

EIGHT-CYLINDER ENGINES

Eight cylinder engines, amounting practically to two four-cylinder engines connected on the same shaft, occasionally have been built. With a gasoline engine of this type, the rotation is so smooth and uniform that it is not impracticable to do without a flywheel.

BALANCE-PISTON ENGINES

A very ingenious method of balancing the moving parts and power impulses of an engine is illustrated in Fig. 21, in which *a* and *b* are two power cylinders, *c* is an idle piston working in a cylinder in which no explosion occurs. The weight of this idle piston and its connecting rod is equivalent to the weight of both

the other pistons and connecting rods; therefore very nearly counterbalances their motion. For the purpose of balancing power impulses the cylinder in which *c* works is made practically air-tight, and the motion of this piston thus alternately compresses and permits to expand a quantity of air above it. As the compression is coincident with the down strokes of the working pistons, the power impulses of which alternate, power is stored in the compressed air above the idle piston and given out on its down strokes, which, of course, are opposed to upward strokes in the power cylinders.

COMPOUND GASOLINE ENGINES

Similar to the preceding engine, in general arrangement of moving parts, is the compound engine illustrated in Fig. 22. In this engine, two high-pressure cylinders, *a* and *b*, are located on

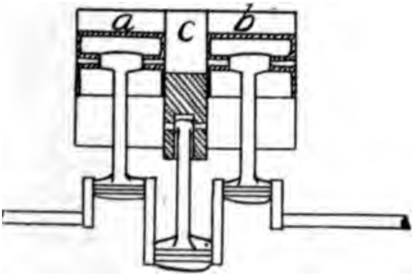


FIG. 21

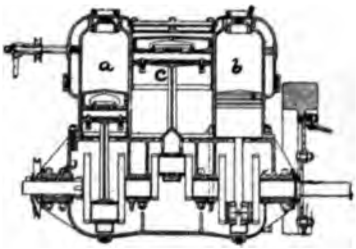


FIG. 22

either side of the low pressure cylinder *c*, in which a piston works which, with its connecting rod, is equal in weight to the pistons and connecting rods in both of the high pressure cylinders. As the crank on which the low pressure connecting rod is attached is exactly opposite those driven by the high pressure cylinders, a very perfect balance in moving parts is secured. To secure balance in power impulses, instead of exhausting into the atmosphere in the ordinary manner, the two high-pressure cylinders, operating on the ordinary four-cycle system, exhaust alternately into the low pressure cylinder in which every down stroke is a power stroke. This engine gives therefore one impulse for every stroke.

It is claimed that a compound engine of this type not only utilizes a greater percentage of the energy contained in a given amount of fuel, but also, on account of the low pressure to which the burnt charge is reduced before exhausting, does away with the necessity for a muffler.

CHAPTER IV.

IGNITION SYSTEMS

The necessity of means for effecting the ignition of each charge of fuel and air in a gasoline engine is obvious. The requirements of an ignition system for this purpose are that it shall produce a flame, or the equivalent, inside the cylinder at a predetermined moment just previous to each power stroke, and then cease to act until the next power stroke. Otherwise no regular generation of power can take place. It is essential, first, to have the ignition occur at the right time; and, second, to have it of only temporary duration.

Electric Ignition. Electricity was the first means used for effecting ignition in internal-combustion engines, and nothing that gives better results has been found. Consequently, it practically monopolizes this particular field.

Electrical ignition systems may be very simple or very complex, according to the various advantages sought to be combined and the disadvantages to be overcome. When one ignition system has to effect ignition in a number of cylinders, its complexity is necessarily increased, while the possibility of having moving parts within the cylinder, opposed by the desirability of avoiding them, is a cause of still further complication.

Broadly classified, there are two systems of electric ignition. One employs the *make-and-break* or contact spark, which is produced between two terminals of a circuit when they are sightly separated, after having been previously brought together; while the other is the *jump-spark* system in which there are two circuit terminals located within the cylinder, separated at all times from each other by 1/32 inch or less, and between which a spark is caused to jump as a result of the high current afforded by this system.

Some make-and-break systems may be said almost to constitute a third type, partaking of some of the characteristics of both the jump-spark and the make-and-break systems, in which mechan-

ical means are used for separating and bringing together the electrodes. These are known as *magnetic-plug* systems, for they consist of a spark plug carrying both electrodes, one of which is immovable, while the other is moved by an electro-magnet located in the base of the plug.

CONTACT AND WIPE-SPARK IGNITION

The simplest conceivable contact system is illustrated in Fig. 23, in which *a* is a projecting contact, attached to the top of the piston head; *b* is another contact, passing through the cylinder head; and *c* is a battery or other source of electricity. In this system, the electrode *a* is electrically connected to the piston, while the electrode *b* is insulated from the cylinder by the insulating material *d*, which completely surrounds it. The wire *e* from one terminal of the battery is *grounded* upon the engine frame at *f*, which has the effect of making the metal of the frame complete the circuit to the electrode *a*. The wire *g* from the other battery terminal is connected to the electrode *b*.

The operation of this system is as follows: As the piston rises, *a* cames into contact with *b*, and then, upon the piston re-

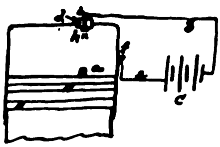


FIG. 23

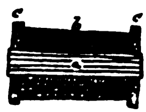


FIG. 24

versing its direction, a spark is produced at *h*, at the moment the two electrodes separate. This occurs as each down stroke of the piston begins and in case the combustion chamber *i* is filled with a proper mixture, will ignite it, thus giving a powerful impulse to the downwardly-moving piston.

While the system just described is commendable for its simplicity, it lacks many features and possesses a number of objections which make necessary considerably more elaborate arrangements to insure practically available results. For instance, a spark is produced at every down stroke of the piston, whereas in a four-cycle engine a spark is desired only for every other stroke. Therefore, the necessity for some means for insuring the absence of any spark upon intermediate down strokes, which are suction strokes, is obvious. Otherwise the mixture would almost cer-

tainly be fired as it entered into the engine, besides which there would be twice as much current taken from the battery *c* as is necessary.

Still another defect in the system illustrated in Fig. 23 is that a battery or other source of electric current that can be conveniently carried along on a motor vehicle is not capable of giving enough current to produce a "fat" spark when a simple circuit from its terminals is made and broken in the manner described. For this reason there is required a ***spark coil***, consisting of a thousand or so turns of insulated copper wire about a core consisting of a bundle of iron wires, the whole arranged as shown in Fig. 24, in which *a* is the bundle of iron wires, *b* the coil of insulated copper wire, and *c c* spool heads for keeping the whole together.

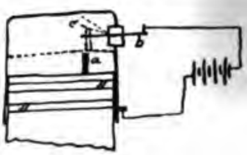


Fig. 25

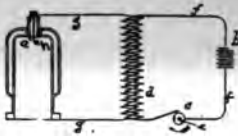


Fig. 26

The action of such a coil, when properly connected in an electric circuit, is to produce a hot, yellow flash between the movable contacts.

A third objection to the system described in Fig. 24 is that the contact points *a* and *b* soon become corroded or coated with products of combustion so that they do not complete the circuit when brought together, with the result that no spark is produced when they are separated.

To obviate this, the general type of contact illustrated in Fig. 25 has been used. In this, *a* is the electrode attached to the piston, while *b* is that attached to the cylinder. The latter consists of a flexible wire, which springs as indicated by the dotted lines, thus permitting *a* to slide against it, as at *c*, thereby producing a wipe action instead of a mere touch or contact. This is what is known as the wipe-contact construction, and has the advantage that all corrosion and objectionable deposits are worn off the contact surfaces by the rubbing that occurs with every contact.

Besides the several objections enumerated, it is found necessary to provide means of varying the time of ignition—again increasing the complication.

An elementary jump-spark ignition system is diagrammed in Fig. 26. In this, *a* is the spark plug, screwed into the cylinder head, *b* is the battery or other suitable source of current, *c* is the contact breaker, operated through a direct or indirect connection with the engine shaft *e*, and *d* is a spark coil to transform the current from low tension to high tension.

When the shaft *e* rotates to the point where the parts of *c* are brought into contact, the circuit *f f* is completed, permitting the current to flow into the spark coil *d*. This coil is made with two windings, and when the low tension current is thus completed through part of it, a current of high tension is induced in the secondary winding, which is a part of the circuit *g g*, with the result that a sudden surge of high-tension current goes through it, breaking down the resistance across the small gap *h* in the spark plug *a*, producing a small spark at this point. The core of the spark plug, it will be noticed, is insulated from the rest of the plug by mica or porcelain, and connects with one of the wires *g*,

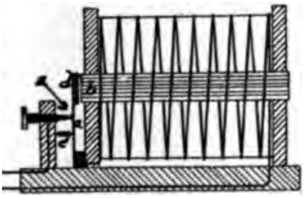


FIG. 27

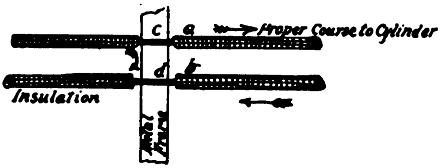


FIG. 28

while the other portion of the spark plug is in electrical contact with the metal of the cylinder, upon which the other wire of the circuit is grounded.

TYPICAL ELECTRIC IGNITION SYSTEMS

The coil at *d*, Fig. 26, which is a typical induction coil, such as is used for the jump-spark systems, consists of four elements, the primary and the secondary windings, the soft iron core, and the condenser. When the current is flowing in the primary winding, the soft iron core becomes a powerful electro-magnet. The magnetism, however, ceases immediately upon interruption of the current. Consequently, it being one of the principles of electricity that an electric current is generated in a wire in the neighborhood of which an electromagnet is brought, an electric current

is induced in the secondary winding of the coil, because of the sudden magnetization of the iron core, this being in effect the same as bringing a magnet into the vicinity. The voltage of this induced current is proportional to the number of windings, which, in turn, are affected by the fineness of the wire, so that a proper balance must be struck in this respect, if required results are to be obtained.

As a circuit is closed but once for each explosion by the contact breaker, a *vibrator* usually is used to insure a sufficient spark action between the terminals of the spark plug to effect ignition. The manner in which the vibrator does this is shown in Fig. 27, in which *a* is a vibrator blade, *b* is the core of the spark coil, and *c* is a spring, normally keeping the vibrator blade drawn away from the core. However, when the core is magnetized, it attracts the vibrator to it by means of an armature *d*. When the vibrator moves thus, the circuit is broken again at *e*, despite the action of the contact maker, so that the magnet is rendered inoperative and the vibrator at once flies back under the influence of the spring. This action continues as long as the contact maker is in position for a spark to occur, and the result is a rapid discharge of short, intense sparks between the terminals and spark plug, instead of a single spark, as would be the case were no vibrator used.

Some vibrators are worked mechanically, instead of electrically, in which case they are commonly combined in the contact maker. A few ignition systems are designed with a vibrator that comes into play when the engine is running at low speed, and is cut out as the speed becomes higher. The reason for this is that at low speed there is not a sufficiently abrupt break in this contact maker to insure a sharp discharge at the spark plug, while at high speeds there is. Thus the vibrator is obviously more necessary for the lower speeds.

A coil having a vibrator uses much more current than one without a vibrator, because of the many more frequent contacts.

The reason for using a bundle of soft-iron wires instead of a solid iron rod for the core of a spark coil is that in a solid mass of metal "eddy" currents are produced throughout its mass, which interfere with its proper action as a magnet. The exact manner in which these currents are set up and their effect upon the operation of an ignition system are matters too complex to treat therein, nor are they essential to the scope of this work.

Control of Ignition. It stands to reason that the ignition of a quantity of mixture in the combustion space of an engine cannot

be instantaneous, especially with electric ignition, although it may be exceedingly rapid. This being the case, it is evident that the time required for complete ignition bears a relation to the piston speed and the various positions at which the piston may be during the progress of ignition from its start to completion, and should, in fact, be so disposed that the charge will be in full combustion the moment the piston commences its power stroke. To insure this, it ordinarily is not sufficient to ignite the charge just as the piston passes the dead center and commences to go down. With this done, it would be found that the expanding force of the exploding gas would not be manifest until the power stroke were nearly completed. Therefore it is customary in all well-designed engines to *advance* the ignition in such a way that the ignition may commence even as early as half way along the compression stroke. This degree of advance may be absolutely essential to make the engine work at its best, the compression being completed and the power stroke started before the ignition is fully under way.

Since engines are run at various speeds, while the rate of flame propagation in a given mixture is practically constant, it is evident that, theoretically, at least, the time of ignition should vary with the speed of piston movement. And this is found to be the case in practice. Thus, if an engine be run very slowly, the ignition requires to be advanced but little, whereas at high speeds the extreme advance just cited may be necessary. The exact amount of ignition advance which should be given a given engine, at any particular speed, is determined by a number of factors which must be ascertained for that particular engine. The fuel used, the correctness of the mixture, the location of the spark plugs, or the point from which ignition commences, all have their effect. A mixture in which the rate of flame propagation is high requires less advance of ignition than is best with slower-burning mixtures. Likewise, if the ignition commences at some remote point in the combustion chamber, the ignition should be more advanced than if the ignition commenced at the center of the combustion chamber.

The size and hotness of the flame or spark that starts the ignition has some effect upon the time taken for the combustion to become complete, and, consequently, upon the necessity of advancing the ignition. Success has been met with in designing ignition systems in which the size and the heat of the sparks vary, thus largely obviating all necessity for advancing or retarding the ignition.

MEANS OF TIMING IGNITION

Since great loss of power results when the ignition is either too far advanced or retarded in a gasoline engine, it consequently is necessary to provide means for advancing and retarding the ignition in exact accordance with requirements. In most motor vehicles, hand control is all that is provided for, but there has been much effort to provide automatic governing means, to advance and retard the ignition without attention on the part of the operator as variations in speed might require.

By proper manipulation of the ignition advance in a properly designed two-cycle internal-combustion engine, these engines may be made to reverse, a result not commonly attained in motors of the four-cycle type.

Briefly stated, this result is produced by first slowing the engine down by retarding the ignition until it does not occur before the power stroke is almost completed, and then suddenly advancing it so that it occurs early enough in the compression stroke to force the piston back. Then, as soon as the engine gets under way, in the reverse direction, the ignition may be again brought to the retarded point, which now, however, is equivalent to advance, because of the opposite direction of motion. The chief use for reversing mechanisms of this character is on motor boats, etc.

In advancing or retarding ignition by hand, a small lever upon the steering wheel, or a small pedal for the foot, is commonly used. The hand lever usually will work over a segment in which is cut a large number of notches, so that the adjustment will hold at any angle.

When any change occurs in the speed of the motor, because of the manipulation of the steering gears, of the throttle, or as a result of variations in the road, the ignition should be gradually advanced until pounding is heard in the engine, which indicates that the explosion is occurring so early in the compression stroke as to be wasting power. Then, by dropping the ignition back a notch or two, the pounding will cease and the ignition be at its point of maximum efficiency for that particular speed. The reason for advancing ignition to the point of pounding is that this is the only way in which it can be made certain that it is advanced enough.

Electric-Ignition System Troubles. Because of the very complicated construction and operation usually involved in electric ignition, and also because of the many factors operating to derange such ignition, electric ignition systems have been, are, and

always will be a source of about as much trouble as arises in connection with any other detail of motor-vehicle mechanics. However, a thorough understanding of the operation of an ignition system, and its proper care and maintenance, will lessen trouble of this sort almost as much as will high-class construction to begin with.

SHORT CIRCUITING

One of the commonest causes of failure of electric ignition is a *short circuit* in some portion of the system. By short circuit is meant a leakage of the current from one point to another in such a manner that it escapes across the circuit, without going to points it is required to reach. For instance, in the diagram shown in Fig. 28, a leakage of current from *a* to *b*, as might be caused by a lack of insulation upon the wires *c* and *d*, with consequent contact upon the metal extending between these two points, would prevent the current from reaching the cylinder.

Short circuits are caused by a breakdown of insulation, which always should be carefully maintained. Thus, the scraping off of this covering, which protects the wires, will permit the current to leak in case the wire comes in contact with a conducting surface. Another form of short circuit comes from deposits of soot, which is a fair conductor of electricity, on the spark plugs, permitting the circuit to be completed without jumping the gaps.

Careless maintenance of insulation and the presence of moisture are the chief causes of short circuits, and both should be given the most careful attention. In case of an ignition failure, to determine whether it is caused by a short circuit, preferably some sort of voltmeter or ammeter, but in an emergency simply a small wire, may be placed across the terminals of the battery or other source of electric current supply. If a proper current is in evidence, as shown by the movement of the index of the voltmeter or ammeter, or by a spark when the ends of the wire are brought into contact, it is certain that there is a short circuit if the sparking plug fails to produce a spark between its terminals.

A short circuit may be complete or partial. For instance, there may be sufficient leakage to prevent satisfactory ignition without the leakage being great enough to keep some sort of a spark from occurring between the terminals of the spark plugs.

The points at which short circuiting is most likely to occur in an ordinary ignition system are: between the various parts of contact breakers, commutators, etc.; between the wires that conduct the current from the spark-coil to the ignition plugs; across the surfaces of the spark plug, or through a crack—usually almost

microscopic—in the spark-plug insulation; between adjacent la of wire in the spark coil; and from the outer terminal of the to the engine cylinder. The presence of water or mud upon s plugs or at any other point in the ignition system is almost ce to cause trouble.

The higher the voltage in the ignition system, the greater danger of a short circuit, because high voltage overcomes resistance, and a short circuit of such resistance that a low-ten current cannot possibly be made to complete it will short ci a high-tension current. It is this that renders short circu especially likely to occur in the secondary circuit of a jump-s ignition system.

CHAPTER V.

CARBURETERS

Little less important than the improvements in the gasoline engine itself have been the improvements in the means of generating the gaseous and vaporized fuels by which it is operated. For this reason, the carbureter plays a most important function in the successful utilization of such engines in many fields, especially in that of the motor vehicle. Consequently the theory and practice of its construction is of utmost importance.

To render ordinary liquid fuels, such as are used in gasoline automobiles, available for power purposes in the cylinders of the engines, it is necessary that they be vaporized and intimately mixed with the right proportion of air to insure their efficient and complete combustion.

Gasoline vapor is merely inflammable. To make it explosive, it must be mixed with air in correct proportions. This process is termed carburetion, and the device by which it is accomplished is called a carbureter. Properly speaking, it is the air that is carbureted, the meaning of the word implying the impregnation of some other substance with a quantity of carbon, the element of which gasoline engine fuels are largely composed.

Great ingenuity has been expended in the production of carbureters that will operate efficiently and without constant attention, and the problem has been by no means so simple as would appear superficially. A mixture too rich in fuel explodes too rapidly and generates an excessive heat, with consequent injury to the motor and excessive sooting of the combustion chamber and exhaust passages, while the fall in pressure resulting from the explosion is very rapid, with a consequent loss of power. A mixture not rich enough is difficult to ignite, but otherwise gives more satisfactory results. The best mixture is always that which produces the most complete combustion and involves the least difficulty in ignition and the most efficient use of the fuel. The difficulties in the way of obtaining such a mixture at all times

are caused by changes in atmospheric conditions, of temperature, pressure, humidity, etc., and by variations in the quality of the fuel. Consequently, a good carbureter must be a very accurate instrument as well as one that will adapt itself without attention to widely varying circumstances.

Types of Carbureters. The devices by which carburetion is accomplished are many, but all depend upon similar principles for their operation and fall into two general classes. Simple evaporation is the means of producing a fuel vapor in both classes, and its admixture with a proper quantity of air completes the process of preparing the fuel. The evaporation is effected by two distinct methods, one of which involves exposing a considerable area of the fuel to the air so as to promote evaporation, while the other involves atomizing the fuel, through a very small nozzle, into a current or a fixed quantity of air. The first pattern is the simplest, but its bulk and weight are considerable and it is difficult to maintain in correct adjustment. The other type, though complex, may be very small and light, and in its best forms is capable of remarkably accurate adjustment and regulation.

Carbureters of the first type are called *surface carbureters*, and those of the atomizing type, *spray carbureters*. Besides these two types of carbureters, there is another means of combining a fuel with the air necessary for its combustion—that of injecting a minute quantity of fuel directly into a cylinder already containing the required quantity of air. A device of this sort, however, does not, in the common sense of the term, constitute a carbureter, although it performs a similar function most satisfactorily, and deserves wider use.

SURFACE CARBURETERS

The simplest conceivable method of producing an explosive mixture is to expose a quantity of gasoline, or similar fuel, to the air in a shallow, open vessel. The liquid will at once begin to evaporate, and, if the resulting vapor is, or happens to become, mixed with a correct proportion of air, the mixture will explode if a flame or spark be brought into it. This result is occasionally brought about unwittingly by the careless use of gasoline in a closed room, in which case a dangerous explosion may happen.

An exceedingly serious objection to the surface-carbureter is that the evaporation at all times is from the surface of the fuel, with the result that the heavier portions are left behind, finally becoming so thick as to be unusable. This type has been used chiefly in early cars and on motor-cycles, but is now hardly ever employed.

Spray carbureters are of two general types. The first type consists primarily of a simple nozzle connected with a pipe leading to the fuel tank, and so controlled that the flow of fuel from it is regulated by the action of some kind of shut-off cock, or valve.

Float-feed carbureters are similar to the preceding type, except that the fuel from the tank is first conducted into a small *float chamber,* in which it is maintained automatically at a constant level. Then, by the arrangement of the nozzle, the fuel stands at all times near the top, but not overflowing, and is drawn out only by the suction of the engine. This arrangement secures a much more accurate result than at present seems possible to obtain without the use of a float. A typical carbureter without a float

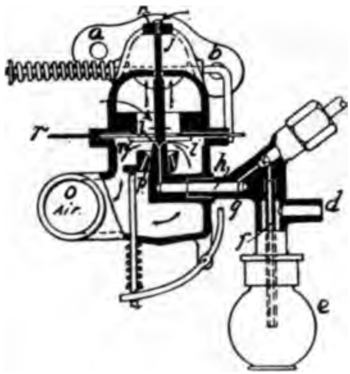


FIG. 29

is illustrated in Fig. 29. This carbureter is bolted directly to the cylinder head by bolts, not shown, and opens directly into the inlet valve *c*. The gasoline is brought from the tank through the pipe *d*, and passes down into a sediment cup and up through another pipe, and out of the nozzle *i*. A needle valve *g* is provided for regulating the rate of flow from the tank, while the sediment cup, which is from time to time filled up with dirt that may have been in the fuel, can be removed. Directly over the nozzle *i* is located the adjustment screw *j*, which can be raised or lowered by the thumbscrew *k* in such manner as to change the size of the opening through which the fuel is permitted to pass at *i*. Below the adjustment screw is the flanged portion *e e*, which is lifted

when a draft of air impinges upon it as a result of the suction within the engine cylinder. The air enters at *o* and passes in the direction of the arrows by the nozzle *i*. A throttle, consisting of a simple slide valve (being merely a flat plate with a hole through it), regulates the quantity of fuel permitted to reach the engine. The handle of the needle valve is so located that it may be readily reached from the driver's seat; consequently it is at all times subject to his control.

Another means for applying fuel that requires to be heated to insure complete vaporization consists in a corrugated cone, or a thin wall, kept hot by jacket space within it, and against which the fuel is projected.

Another float feed carbureter, in many respects typical of numbers of such devices, is shown in Fig. 30. In this carbureter,

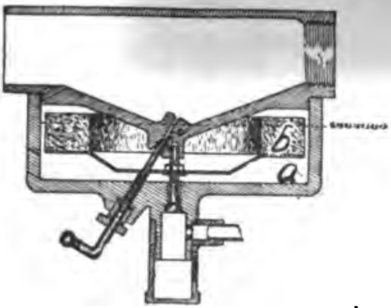


Fig. 30

a is the float chamber, and *b* is the float. It will be noticed that the float is annular in form, consisting of a ring completely surrounding the spray nozzle *c*. The purpose of this is to insure at all times an invariable fuel level in the nozzle, regardless of any variation in the level of the road surface.

With the carbureters illustrated in Fig. 31, it is obvious that if that at the right be tilted to the left the fuel will overflow the spray nozzle, while if it be tilted to the right the fuel will drop so far back in the spray nozzle as not to be sucked out readily, with a consequent weakening of the mixture.

In most carbureters the design is such as normally to maintain the fuel close to the top of the spray nozzle.

In Fig. 32, the valve controlled by the float is located at one side, a lever connecting it with the float. When the float rises,

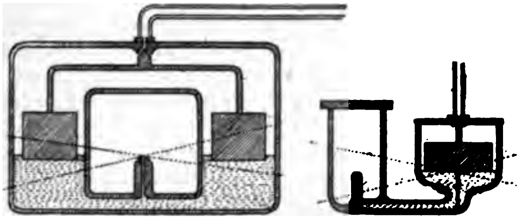


FIG. 31

the tapered pin is forced down into its seating, closing off the flow of fuel, which comes in from the tank. A screen consisting of a number of layers of wire gauze, filters the fuel before it reaches the float chamber.

Carbureter floats are in many cases made of cork or wood, coated with a varnish impervious both to gasoline and water. Such floats avoid an objection to metal floats, which is that these often develop microscopic leaks, and then become unduly heavy through a quantity of fuel that percolates into them. Such a leak may cause a serious and sometimes very mystifying irregularity in the action of a carbureter.

An objection to types of float-feed carbureters, such as so far have been described, is that the mixture they deliver increases in richness with any increase in the speed of the motor. This is because the more powerful suction that results from high engine speed has less marked an effect upon the air admission than it

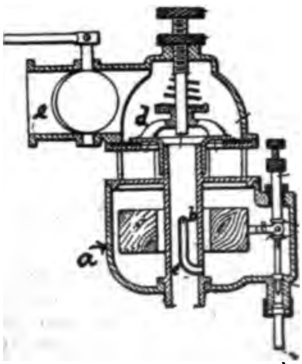


FIG. 32

has upon the fuel jet, since the tendency of the air to rarify, or "stretch out," so to speak, is accompanied by a tendency of the stream of liquid fuel to flow for an appreciable period after the suction has ceased. The considerable momentum of the liquid, which is heavier than air and, unlike it, is not expansible, is

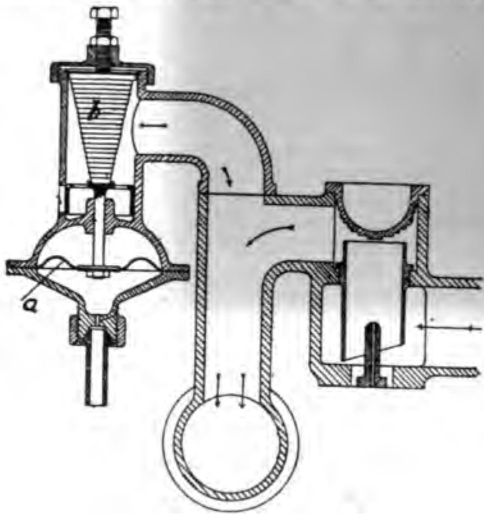


FIG. 33

responsible for this. It is evident that this action must materially increase the richness of the resulting mixture at high speeds.

Because of the foregoing, what are known as *compensating* or *automatic* carbureters are coming into use on all well-designed gasoline motor vehicles.

Compensating carbureters are ones in which there are means provided for progressively choking off the fuel admission, or increasing the air admission, in proportion as the speed of the engine increases. There are several recognized systems for arriving at this result.

The carbureter illustrated in Fig. 32 is made with a float chamber *A*, containing a float, as shown, controlling the height of fuel in the atomizing nozzle *B* in the usual manner. The main air supply is at *C*, whence the air passes over the atomizing nozzle, and down under the valve *D*, and up through openings in the

enter of this valve, and into the pipe *E*, leading to the valve of he engine. When the suction is increased beyond that giving a ormal mixture at low speed, it causes the valve *f* to open, with consequent admission of additional air, which both dilutes the iixture and lessens the violence of the suction upon the atomizing ozzle, with the result that the fuel supply is reduced at the same ime the air supply is increased.

Other carbureters, similar to the foregoing, possess an auxiliary ir inlet on which works an ordinary poppet valve, similar to an utomatic inlet valve, held in place by a spring.

Another means of rendering carbureters automatic or com-ensating is shown in the carbureter illustrated in Fig. 33, in which *a* is a diaphragm regulator by means of which exhaust pressure iverted from the engine controls the valve *b*, with a consequent ariation in the amount of air admitted just sufficient to insure correct proportion at all speeds.

Various compensating carbureters are in use, in which the uxiliary air admission is controlled directly by positive mechan-al connection with a governor the action of which is dependent pon the engine's speed. Dependence upon suction is thus voided, but the compensating action cannot always be accurate. This is because the suction of a gasoline engine upon the carbu-eter is not necessarily always in proportion to the speed at which he engine is run. For instance, with an engine maintaining a peed of 1,000 revolutions a minute, in the one case on a level and n the other up a grade, it is evident that in the first case less fuel vill be required than in the latter, and that the suction will be orrespondingly less, because of the action of whatever means of hrottling may be used to control the engine. Therefore, a system hat admits extra air to a carbureter upon a mere increase in ngine speed will dilute the mixture unduly in case the power lemand upon the engine happens to be very light, the going on a evel or down grade involving small fuel consumption. Con-ersely, if the admission of extra air is reduced for the simple eason that the engine is running slow, as in the case of its labor-ng up a grade, the mixture will be too rich, consequent upon he full aspirations of the motor on each stroke, due to the great ower demand.

This point of distinct difference seems, unfortunately, not al-ways to be borne in mind by designers of carbureters. Evidently t is necessary to provide for automatic regulation not only upon a change of engine speed, but also upon any variation in the hrottle opening. An engine running at very high speed, with a

nwardly projecting atomizing nozzles, all c
y closed by small leather pads attached t
h bear springs of varying tensions, permittir

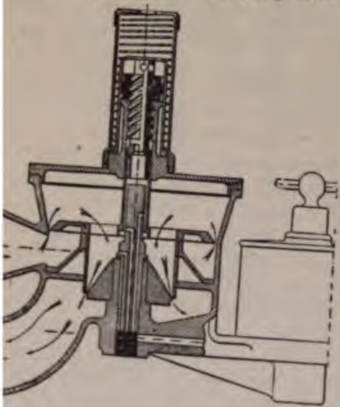


FIG. 34

FIG. 35

nozzles to open as the suction increases.
ing nozzles have been employed in carburete
other means of providing automatic carbure
the use of a regulating valve controlled by

quantity of fuel as the engine speed increases, are better. This is because an explosive mixture somewhat weaker than that giving the maximum efficiency possesses a greater rapidity of flame propagation, and therefore is more suitable for high piston speeds.

A means of most exactly adjusting a carbureter to the work required of it is suggested in the use of two diaphragm valves, one controlled by the exhaust pressure of the cylinders, and the other by pressure of the circulating water, latter to proportion the rapidity of ignition or flame propagation to the speed of the engine, and the first to compensate the mixture to the suction. Exhaust pressure is in all cases proportionate to the suction pressure, being dependent upon the amount of fuel admitted on a preceding stroke,

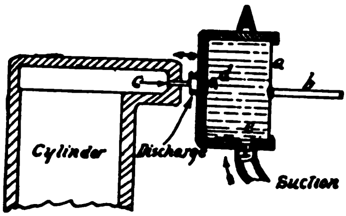


FIG. 36

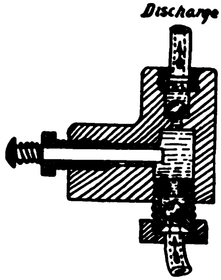


FIG. 37

and it being impossible to throttle an engine so rapidly as to produce a change in less than several strokes.

It is necessary, in designing a carbureter, to remember that the best results so far always have been obtained by empirically calibrating carbureters, that is to say, by testing and adjusting at different speeds, and measuring both the volume and proportions of the mixtures produced. Absolutely reliable data have been thus secured for the adjustment of the compensating action and the proportioning of the air and fuel passages, with results far superior to any attainable by merely theoretical figuring.

POSITIVE-FEED CARBURETERS

Numerous attempts have been made to measure definitely the amount of fuel mixed with the air taken in by each suction stroke of an engine piston, with a view to securing exact results, but the exceedingly small amount of liquid fuel necessary for a single stroke of an engine, has been a stumbling block in the way of developing satisfactory carbureters of this type.

One of the means by which such a result has been attained is that illustrated in Fig. 36, in which *A* is a small *diaphragm pump*, directly attached to the cylinder wall, and so arranged that alternate pull and pressure upon a thin metal diaphragm *a*, by means of the rod *b*, pumps a minute quantity of fuel direct into the cylinder through the orifice at *c*. The valves *d* and *e* force the liquid always to proceed in the proper direction.

Another pumping device is shown in Fig. 37.

MISCELLANEOUS CARBURETERS

Mixing valves in a way meet the purpose of carbureters, but usually are devices designed only for mixing a fuel that already is gaseous with the proper proportion of air. The functions of a carbureter, however, include not merely the mixing of the fuel with the air, but also the vaporizing of the fuel.

Mixing valves that introduce a quantity of gasoline or other

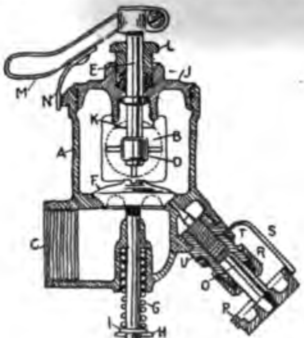


FIG. 38

fluid fuel, are properly to be considered as carbureters, and generally approach in construction the carbureter illustrated in Fig. 29.

A typical mixing or "generator" valve is illustrated in Fig. 38.

Alcohol carbureters require to be heated from 392° to 480° F. to insure perfect vaporization. This heating usually is performed by exhaust gases from the engine cylinder or hot water from the cooling system.

More air is required for the complete combustion of a given quantity of alcohol vapor than is necessary for the combustion of gasoline vapor, which must be taken into consideration in the

designing of carbureters for this fuel. Moreover, a larger carbureter for a given power is required when alcohol is the fuel, for as much as 50% more alcohol may be required for a given power output than is necessary with gasoline.

Most carbureters designed to work with alcohol also will work very well with gasoline, but the reverse does not hold good, for gasoline carbureters are not very often provided with means of heating.

Kerosene carbureters are similar in construction to those used for alcohol and gasoline, except that considerable heating is required. Probably the best results in using kerosene as a fuel are gained by starting the engine upon gasoline, and then supplying kerosene after it has been sufficiently warmed up. In default of gasoline it often is possible to run very successfully with kerosene as a fuel, provided the carbureter and engine cylinder are thoroughly heated to start.

Various Points in Carbureter Design. The plunging of a poorly-sprung car, or of a car going over a very rough road, and especially at high speeds, affects the action of a carbureter by jarring both the float and the liquid in the float chamber. The consequent alteration in fuel level alternately impoverishes and enriches the mixture by retarding the fuel flow, or by causing flooding through its undue rise in the atomizing nozzle.

Carbureters not provided with compensating means, and even some of the latter type, should possess some device for regulating the air or fuel flow by hand. Control of this sort facilitates setting the carbureter for the most diverse weather conditions, and is especially advantageous in adjusting carbureters to atmospheric humidity. It is unquestionably a fact that a smaller quantity of dry air is required for a given result than is necessary if there is much moisture present in the atmosphere, and so far no carbureter has appeared with means of compensating for this cause of variable action.

It is somewhat of a question whether all carbureters should not be provided with means of heating, since even the most volatile fuels tend to give poor results in cold weather. Moreover, evaporation exerts a refrigerating action, which aggravates the effects of extreme cold.

Even in weather not at all cold frost is sometimes formed in the induction pipes of carbureters, because of the precipitation of moisture from the incoming air. If a carbureter clog up in this manner, it is best to wrap it with cloths wrung out in hot water. In fact, it is an excellent plan to warm some carbureters before attempting to start in cold weather.

When a carbureter is kept too warm, or is supplied with air or fuel too warm, the efficiency of the engine is lowered to a marked degree. Carbureters provided with means of heating also should be provided with means of regulating the temperature to make them constant in operation regardless of external temperature. Moreover, it is a point to consider that what requires heating is the fuel portion of the charge and not the air, because heating of the latter expands it, with the result that not so much is got into the cylinders, followed by proportionate reduction in power output. Carbureters provided with extensive water jacketing are often serious offenders in this respect. That type in which the only heating provided is that of a hot wall upon which the fuel jet impinges, is unquestionably calculated to give better results.

Carbureter Troubles. A frequent cause of trouble in float-feed carbureters is variation in the level of the fuel. A rise in level generally is caused by a leaky valve, which does not shut off completely when the float rises; or by a float that has leaked until sufficiently filled with fuel to sink so deeply that it does not shut off the supply from the tank until the level of the float chamber is abnormally high.

Too low a level of fuel in the float chamber may be caused by clogging of the pipe from the tank, as a result of impurities in the fuel, or by the presence of water in the float chamber, which lifts the float too high and shuts off the fuel supply too soon.

Simple means of draining the float chamber are provided in almost all carbureters, and draining and cleaning should be done every 500 or 1,000 miles, as the carbureter may seem to require it.

A leaky float may be emptied by punching a small hole at a point opposite the leak and expelling the gasoline through one of the openings by blowing through the other. If the leak is very small, the float can be replaced and considerable distance made before it is again so filled as to work badly.

In case the leak is larger, it must be soldered, using as small an amount of solder as will suffice, so as not to make the float weigh more than it should.

Sometimes shaking a float will show it to contain gasoline even though no opening be perceptible. To find such a microscopic leak, the easiest way is to immerse the float in very hot water, which will quickly cause bubbles of gasoline vapor to escape, thus showing the situation of the leak. By then turning the float until the leak is at its lowest point, the heated vapor within will expel the liquid. The moment it is all out, as shown by occasional shaking, the float should be removed, else the condensation of the

vapor will create a partial vacuum, sucking in water that will be quite as injurious as was the gasoline.

Leaky needle valves in carbureters, resulting in failure of the float to shut off the fuel completely, can be remedied by replacing or regrinding. Many motorists make it a point to carry along extra floats or valves, to permit quick replacement in the event of trouble. If this is not done, grinding becomes a necessary roadside repair. To grind the stem of a needle valve, it should be twirled between the fingers while its point bears upon its seat, a small quantity of fine abrasive material, such as powdered glass, or grindstone dust mixed with oil, being applied to it. Emery may be used, but it usually is unnecessary because carbureters are in most cases built of soft brass or of aluminum, and is objectionable inasmuch as small particles of it almost invariably remain and aggravate future wear.

If a float maintain too low a level of fuel through premature shutting off of as a result of faulty design, it may be loaded with a small amount of solder until it sinks deep enough into the fuel to work properly. Carbureter floats generally are designed with considerable depth and thus sink materially into the fuel, in which case the point at which they will shut off will vary materially with the specific gravity of the fuel used. Thus, if a heavy grade of gasoline is employed, the float will float higher and the fuel stand at a higher level than if a liquid of lower specific gravity is employed.

For this reason, very shallow floats are capable of working with the widest range of fuels because of the smaller possible variation in float level than can follow upon any variation in specific gravity of the liquid in the float chamber.

A cork float is much easier to adjust than a metal one, because it may be lightened by trimming, or made heavier by weighting. With a metal float it sometimes is found necessary to set the float higher or lower upon the needle valve rod to secure satisfactory adjustment.

If a carbureter does not supply sufficient fuel to an engine, it is possible that it is too small, in which case a new one should be fitted. In selecting a carbureter for a given engine, one should be chosen having an outlet pipe slightly larger than the inlet-valve opening into the cylinder. For instance, an engine with an inlet valve opening 1½ inch in diameter should be fitted with a carbureter having an outlet about 1⅝ inches in diameter. More often, however, such trouble is due to the fuel standing too low in the spray nozzle.

An increase of about 1/100 inch in the diameter of a spray nozzle is a means of increasing materially the amount of fuel supplied to a carbureter. Such remodeling, however, is only permissible when done under experienced advice.

Running out about a cupful of gasoline from a carbureter once every two or three weeks, usually will clean away any sediment or water that may have gathered. Thorough dismounting and cleansing is required at somewhat greater intervals. A carbureter not so constructed and located that no hardship is imposed by this requirement, may be considered a product of bad design.

Many carbureters are provided with screens consisting of wire gauze, cotton or abestos fiber, variously located within them, but even these do not prevent the accumulation of dirt in quantities sufficient to choke the spray nozzle and block the needle valve, in time thus upsetting the mixture.

Sometimes an aluminum carbureter will be found to contain a white deposit. Pure aluminum, however, does not seem to be the least affected by pure gasoline, even when left in contact with it for months. Nevertheless, there is no question but what some alloys of aluminum with other metals are acted upon by gasoline, and that the impurities in poor gasoline may act even upon pure aluminum.

Alcohol acts upon both cast iron and aluminum, for which reason carbureters for this fuel are better made of brass or bronze.

CHAPTER VI.

GOVERNING AND COOLING

As motor vehicles are required to run at different speeds, it is obvious that devices must be adopted for controlling at will the rate of engine rotation. While change-speed mechanisms may vary the rate of car speed, they are only to be used where the exigencies of travel necessitate their use, and wherever possible, the rate of travel should be controlled through the engine.

Methods of Governing. There are six distinct methods used in the governing of gasoline engines. The first is by varying the intensity of the explosion through alterations in proportions of the mixture, the second is by varying the intensity of the explosion through throttling the mixture, the third is by varying the intensity of the explosion through retaining part of the exhaust gases, the fourth is by changing the time of firing the mixture, the fifth is by missing explosions, and the sixth (applicable only to multi-cylinder engines), is by cutting in or out one or more cylinders from firing.

GOVERNING BY THROTTLING THE MIXTURE

It is obvious that if a gasoline engine draws in a full charge a certain amount of power will be developed with the ignition set at a given point. If, now, the engine draw in one-half or one-quarter as much as before, the power developed will be decreased correspondingly with the intensity of the impulse varying proportionately; this is termed throttling the mixture and is the system most employed in motor-car practice. The throttling devices most employed to regulate the amount of mixture drawn into the cylinder are a throttle valve in the inlet pipe; means of varying the lift of the inlet valve; means of varying the duration of the inlet-valve opening; by the system of drawing in a full charge and thereafter forcing out more or less through the inlet valve, which is kept open longer than ordinarily by mechanical means.

GOVERNING BY ALTERING THE MIXTURE

One method of governing is by altering the mixture: that is to say, one component is kept constant (preferably the air) and the other is varied. This method is almost always used with the pump system of fuel supply and is the best possible for regularity of action and high fuel economy. This is so because of a number of reasons. For one thing, gasoline engines are so dependent for fuel economy upon proper compression that under light loads the throttled-mixture method results in a very low compression, perhaps none at all, so that for fuel efficiency the throttle method is extremely wasteful. The method of varying the mixture by drawing in the same amount of air and more or less gasoline insures full compression at all loads, with a consequent high fuel efficiency. This method is becoming generally prevalent with the large stationary internal-combustion engines now in use. The high compression compensates for all variations in proportion of mixture, one part of air to 80 parts of fuel being ignited very easily.

GOVERNING BY VARYING IGNITION TIME

If a mixture be ignited when the piston is at its upper dead center, it is evident that the full pressure will act upon the piston throughout the entire working stroke. When, however, the spark is set to occur later, the piston will have traversed a considerable portion of its stroke before the impulse acts upon it. Thus only a portion of the energy available can be utilized. Another feature is that when the engine is rotating at a considerable speed, as explained before, ignition must occur before the piston has reached the end of its compression stroke. In this case, even if ignition occur at dead center, the available power is cut down considerably. Ignition by spark control therefore is a wasteful method of governing, because the full benefits of the charge are not obtained. It is, nevertheless, very useful in some cases for obtaining very low speeds of rotation.

GOVERNING BY RETENTION OF EXHAUST GASES

Combustion in a gasoline engine is the chemical union of a mixture of air and the hydrocarbon used, accompanied by the evolution of heat. If, therefore, this mixture be diluted with any portion of the burnt gases from a previous explosion, these burnt gases, consisting largely of carbon-dioxide and nitrogen, and being non-supporters of combustion, will check the combustion to a

degree varying with the proportion of burnt gases present. To utilize this condition as a method of governing, more or less of the burnt gases are retained on the exhaust stroke, and on the suction stroke the remaining space in the cylinder is filled with fresh mixture, which is compressed and fired in the usual way. This method has the advantage of the economy due to fixed compression for all loads, but is at fault in that the residual gases interfere with the combustion. This system is rarely used in motor-car work but finds some application in stationary-engine practice, and has been widely applied to motor-cycles.

GOVERNING BY MISSING EXPLOSIONS

A governing method that finds wide application in stationary practice but which has been abandoned in the automobile field is that known as the "hit-and-miss system." This system fires a full charge regularly under full load, but under other circumstances intermits these with longer or shorter periods during which no fuel charges are inspired, or at least are not fired. With automatic inlet valves in this system, when the load is lightened the governor holds the exhaust valve open, so that no suction is formed in the cylinder to open the inlet valve. In another design, the inlet valve is allowed to open, but the fuel supply is cut off and the engine makes a number of revolutions drawing in and expelling pure air. This insures that when the governor does allow a new charge to be drawn in a very strong explosion will occur. In this way, a very high fuel economy is secured because every impulse is preceded by full compression. Its use in motor-car work is undesirable because of the intermittent action, which it is impracticable to neutralize by as heavy flywheels as would be required.

GOVERNING BY CUTTING IN OR CUTTING OUT CYLINDERS

A governing system used in multi-cylinder engines, and which resembles the preceding method, is by cutting in or out of operation one or more cylinders, varying with the work done. Its widest application was with two-cycle engines that were not capable of much throttling. By throttling to a small degree, speed could de reduced to some extent, while for further reduction, one or more cylinders were cut out of action, in respect to both ignition and mixture. This system causes much vibration and has been abandoned as other methods have worked out to better advantage.

Means of Governing. The two means of governing control

are: those which are automatic—being taken care of by the engine itself, and those dependent for their operation on the will of the driver.

HAND GOVERNING

The systems of governing in general use being by throttle and by spark, the control of these functions generally is located so that either the hand or the foot can regulate them. Those using the hand control generally place the throttle and spark lever in close proximity to the steering wheel or lever. A typical wheel control is shown in Fig. 41, in which a notched circle is placed at one side of the wheel to retain the throttle handle *b*, while

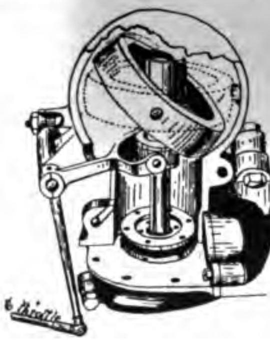


FIG. 39

around the other side the spark lever *c* swings. Other systems place both levers above the wheel, retaining them by sectors placed one above the other or with the same sector, in which case the two levers are separated by a dividing bar. In all ordinary systems, the levers are connected to the throttle and to the timer on the engine by levers and bellcranks, or by wire cable with spring return. Another system of control involves placing either the spark or the throttle, but generally the latter, in relation to a foot pedal so that depressing this opens the throttle. Usually the spark in such a case is placed under the steering wheel and set by hand to suit the varying speeds of the motor.

AUTOMATIC GOVERNING

A very neat way of governing is by the automatic method, by which every variation is accomplished gradually and in proper

relation to engine speed. This is especially true of the ignition side of the problem. If a motor is running at high speed with the spark well advanced and, through going uphill or other exi-

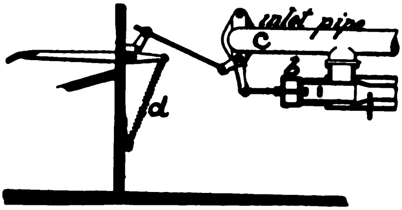


Fig. 40

gencies of travel the car speed is reduced, unless the spark is retarded the motor will pound. If, however, the ignition be under control of a centrifugal governor, as the engine slows down the spark will be retarded gradually but in proper relation to the engine speed, so that it is always set to give maximum efficiency. A typical device of this sort is illustrated in Fig. 43. Another type of automatic governor is used on the throttle and set for a minimum speed, so that for regular running the throttle can be opened through foot or hand control, but if the clutch be thrown out the engine will not race, the governor holding it down. Such a throttle governor is shown in Fig. 39.

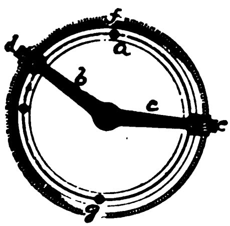


Fig. 41

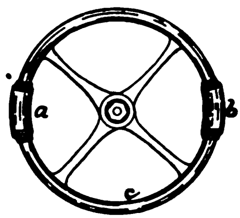


Fig. 42

TYPICAL GOVERNING MECHANISMS

A typical foot control is shown in Fig. 40, in which *a* is the foot pedal connecting through the link motion with the throttle *b* of the inlet pipe *c*. By pressing down the foot, the throttle is opened, and upon releasing the foot pressure the spring *d* closes the throttle.

A hand controlling system is illustrated in Fig. 41, in which a notched circle *a* is fastened to the steering wheel. The arms *b* and *c*, which control throttle and ignition, respectively, are made of spring steel so that they can be lifted up and moved readily. For fine adjustment, the worm wheels *d* and *e*, fastened to the ends of *b* and *c*, are rotated gradually, the worm mechanism engaging with the notches on the circle. This gives delicate adjustment and provides against jarring out of place through vibration or shock. The unnotched portions *f* and *g* provide against the overrunning of the worm wheels.

A system of control is that illustrated in Fig. 42, in which the steering wheel, *c*, has inserted in its rim the two grips, *a* and *b*, for throttle and spark respectively. By twisting these grips they act on the carbureter and timer through the intervention of levers.

A system of control used at one time by a prominent American manufacturer had the spark lever attached to the throttle, so that upon opening the throttle the spark was advanced automatically. This necessitated starting the engine with the throttle almost closed, to guard against a back kick. It had the further disad-

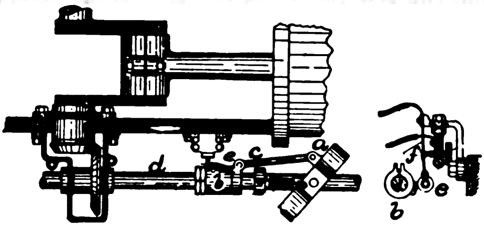


Fig. 43

vantage, where the engine was at low rotative speed when pulling on hard service with throttle open, of igniting too early, causing pounding.

A typical automatic ignition governor is illustrated in Fig. 43, in which *a*, the governor weight, when thrown out by centrifugal force moves the spiral cam *b*, through the link *c*, along the slot *d*. The spiral cam *b* thus is made to operate the roller *e* sooner or later, so that the time of the electrical contact is varied at the points *f*. When the engine starts, the ignition is sure to occur with retarded spark, so that the possibility of back kick is eliminated. As the engine speeds up, the spark is advanced proportionately. The cam can be constructed so that above a certain rotative speed, no electrical contact can take place, thus rendering racing of the engine when the load is taken off an impossibility.

Cooling Systems. Since the combustion of the fuel in a gasoline engine necessarily is attended by very high temperature, means for cooling an engine cylinder are necessary to keep it from becoming so hot as to break down, or certainly to destroy the lubricant used between the piston and cylinder. This fact has led to the general equipment of all motor-vehicle engines with some sort or another of a cooling system for keeping the engine temperature down to the desired limit.

PRINCIPLES OF COOLING

There are many misconceptions entertained in regard to cooling. For instance, it is often imagined by otherwise competent engineers and manufacturers that it is sufficient to keep a lubricant from vaporizing or burning, and a cylinder from melting, to make a cooling system all that it should be. Others imagine that an engine should be kept as cool as possible, and that the cooling system that keeps the engine the coolest is the best. Neither of these is correct.

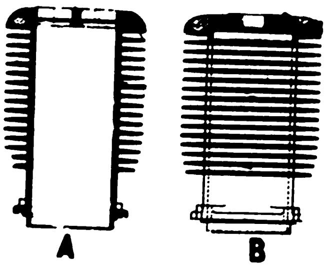


Fig. 44

It is quite possible to cool an engine too much, in which case the cylinder walls and piston abstract such an amount of heat from the burning fuel as seriously to lower the engine efficiency. In fact, an engine kept down to ordinary atmospheric temperature will give from ten to twenty per cent. less power than it would if maintained at 212° F.—the temperature of boiling water. Conversely, merely to avoid actual breakdown of the metal and lubricant is not sufficient, as many air-cooled engines which attain excellent results in these respects nevertheless run so hot that the volume of the incoming charge is so much reduced by expansion as it enters that there is a serious loss in efficiency.

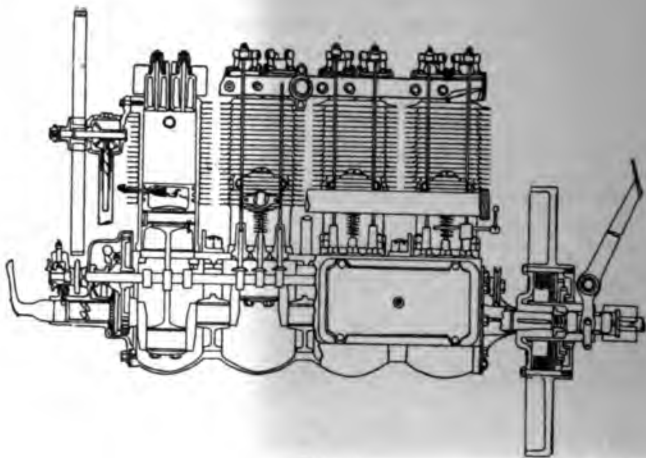


Fig. 45

AIR COOLING

The simplest method of cooling a gasoline engine is by air in contact with the outer surface of the cylinder. Either the air normally in contact with the cylinder, or air brought into contact with it by means of a fan or blower may be depended upon, the latter course producing the most marked effect.

With very small cylinders, the outer area of the plain cylinder

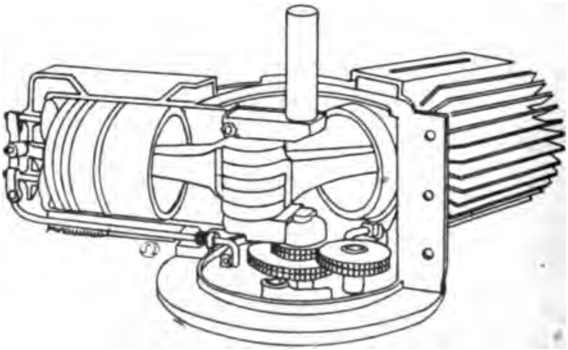


Fig. 46

itself is sufficient for satisfactory cooling, but with large sizes it becomes necessary to increase greatly the area of cylinder surface by providing it with flanges, pins, ribs, etc.

In its simplest form, an air-cooling system consists of nothing more than the cylinder itself in contact with the air. More elaborate systems involve the provision of radiating members, with the addition, perhaps, of air passages so arranged as to bring a maximum quantity of fresh air to the cylinder at all times.

Typical engine cylinders, flanged for air cooling, are illustrated at *A* and *B*, Fig. 44. The flanges shown on the cylinder are cast integral with it, and are so designed as to give an enormous area of radiating surface.

Another cylinder intended for air cooling is shown in Fig. 46, in which longitudinal ribs are provided instead of flanges. Still another type is that shown in Fig. 47, in which numerous pins, studded into the surface of the cylinder, take the place of the ribs or flanges.

Two points that have been considered in the designing of cooling systems are that metals differ materially in their heat conductivity—that is to say, in their capacity for carrying heat away from the cylinder, and that surfaces vary in radiating efficiency. Thus a copper rod of given cross section will conduct at least seven or eight times as much heat from a given point to a given point as is conducted by an iron rod of the same size, and a polished silver plated vessel filled with boiling water will take several times longer to cool than is required by the same vessel coated with lampblack paint. From these facts, the policy of using iron flanges cast integral with the cylinder, when attached flanges of copper seem equally available, has been questioned. Likewise, the use of brightly tinned radiators has been generally condemned in favor of ones finished in dull black.

It can be easily demonstrated that a flange made of iron cannot be made as large in diameter as one of copper in a given situation, if it is to conduct heat clear to its outer edge and thus utilize a maximum radiating surface. Correspondingly, a brightly polished flange will not throw off nearly as much heat in a given time as one that is dark in color and corroded. The latter holds especially true when radiation rather than convection is depended upon for dissipation of the heat units. Because of the foregoing, a much-favored combination for air-cooled cylinders has been that of copper for radiating members and lampblack paint for radiating surfaces.

The necessity for a fan to blow air upon a cylinder is apparent

may be working at its maximum duty and thus tend greatly to overheat. At the same time, the draft caused by the onward movement of the vehicle is so reduced as to be of little advantage in facilitating cooling. This, therefore, is a condition whch renders the use of a fan or some equivalent imperative.

A cylinder having an enormous amount of radiating surface is illustrated in Fig. 48. The cylinder is cast smooth, and after cleaning, coils of wire are placed upon it and the whole assemblage is placed in an electro-plating bath, so that the coils are copper plated to the cylinder. With the auxiliary exhaust port shown, and a fan, the engine operated very satisfactorily with compressions as high as 68 pounds to the square inch.

It recently has been asserted that air cooling is materially

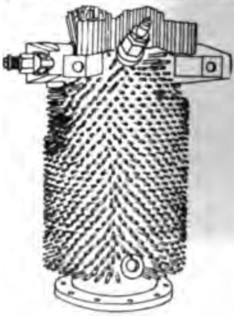


FIG. 47

FIG. 48

assisted by the admission of air to the interior of a cylinder, as in the case of the engine illustrated in Fig. 49, which is built upon this principle. This engine, in common with those that dispense with crankcases, draws cool, atmospheric air behind the piston upon every stroke, the ventilating stack *a*, covered with the screen *b*, being provided for the purpose of retaining the lubricant and keeping out dust and dirt, while air is at the same time freely admitted. It is not probable that air introduced in this manner has a very material effect in cooling the metal of a cylinder itself, but it certainly must tend to cool the lubricant very considerably, and this, after all, is one of the chief points in gasoline-engine cooling. A defect of this design would seem to be the impossibility of a complete exclusion of dust and dirt, while insuring the free admission of air.

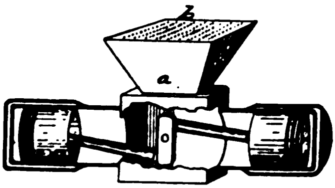


Fig. 49

The heat developed by a gasoline engine is most concentrated at the head of the cylinders and is most likely to cause trouble in the neighborhood of the exhaust valve, through which the exceedingly hot gases are emitted immediately after every power stroke of the engine. Consequently, with most all cooling systems an effort is made to secure the maximum cooling effect at this point.

A system of air cooling which looks to be very reliable and efficient is one that is illustrated in Fig. 50. The cylinders are cast separately, as shown in greater detail at *a*, in Fig. 51, and have small pins about 1/8 inch in diameter and 1/4 inch long, cast integral. The combustion chamber is flanged, and the valves are operated at right angles to the cylinder axis. Over these cylinders the light aluminum jackets, *b*, are placed, being held in position by the small pins mentioned before. The tops of the jackets are open and connect to a bus pipe, *a*, Fig. 50, through which a large

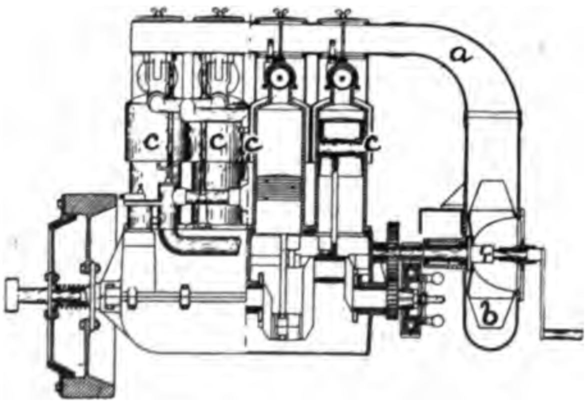


Fig. 50

volume of cold air is forced by the blower *b*, operated from the main shaft by gearing. This cold air impinges on the flanges of the cylinders, thoroughly cooling the valves, and passing between the cylinders and jackets *c*, abstracts the heat from the small pins. In this construction no dependence is placed upon radiation, nor upon the motion of the motor car through the air. The motor is thus kept as cool running with the car standing as when going at full speed.

WATER COOLING

The use of water applied to the walls of cylinders, etc., affords a very efficient and easily regulated system of cooling. Water-cooling systems are in use on by far the majority of all motor vehicles and internal-combustion engines generally, and seem to hold their own despite the material advances in air cooling.

The first essential to a water-cooling system is a sort of jacket,

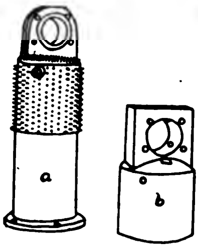


FIG. 51

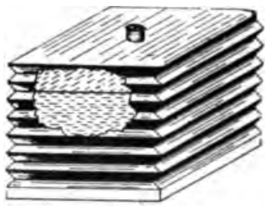


FIG. 52

surrounding the cylinder, valve chamber, and exhaust passages, for containing the water in contact with it. Besides the *water-jacket* for a motor-vehicle power plant, some sort of a *radiator* is necessary for cooling the water by means of air. Besides the radiator, a *tank* may be provided for containing the main body of the water. *Valves* and *pipes* are necessary to direct and control its flow and a circulating pump, or some equivalent, is necessary for keeping the water in motion through the waterjacket, radiator, etc.

Waterjackets have been fully described in a preceding paper under the head of cylinder construction, so their construction will not be entered into here.

Radiators are constructed in many forms, all, however, having as their object the bringing of the water into contact with as large an area of air-cooled surface as possibly can be provided

within small weight and bulk. An exceedingly simple radiator is illustrated in Fig. 52, which consists of a copper tank with a corrugated wall, so as to increase the area exposed to the air. This radiator was actually used on an early American automobile. With the progress of automobile development, there has been constant improvement in the way of making radiators more and more efficient, and capable of providing excellent results with a minimum of water.

The first attempt at making a really scientifically designed radiator resulted in the construction shown in Fig. 53, which is still much used. This radiator consists simply of a long pipe, or of a plurality of pipes, provided with closely assembled disks throughout its length. By circulating the hot water in the engine jacket through a radiator of this sort, its rapid cooling is effected by the disks and returned to the engine at a very much lower temperature. Disk-pipe radiators vary somewhat in the details

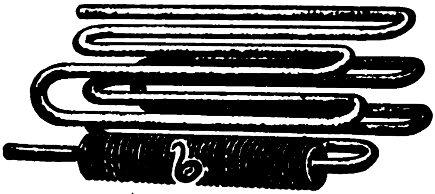


Fig. 53

of construction. The simplest consist merely of plain copper pipe over which circular disks are slid, each being slightly dished out at the center so as to hold at a right angle to the axis of the pipe. They then are soldered in place.

Another construction involves the use of disks with beaded edges, as shown at *b*, Fig. 54, by which they are considerably stiffened and their surface somewhat increased. In other instances, square instead of round disks are used and with disks of this type it is possible to assemble the pipes into very neat form.

A highly meritorious construction is shown in Fig. 55 in which a plain pipe is used, surrounded by a helix-like flange, formed by a straight copper band, crimped so as to fit evenly on the pipe, and soldered tightly to it.

The maximum of refinement in radiator construction is the honeycomb radiator, illustrated in Fig. 56. This radiator consists of a great number of small tubes, preferably hexagonal, but not infrequently round, square triangular, or of other form, either soldered into two plates that form the two faces of the radiator,

or fastened together without such plates. The water in this radiator surrounds the tubes, being admitted at the top and taken out at the bottom, while the blast of air sucked through all the tubes produces a very marked cooling effect, sufficient to permit a thirty or forty horsepower engine to be cooled satisfactorily

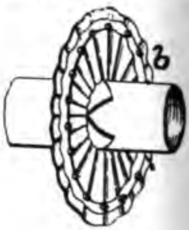


FIG. 54

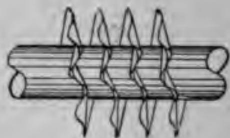


FIG. 55

by the use of a few gallons of water, the only tank in this cooling system being the radiator itself.

Some honeycomb radiators present as much as ninety square feet of cooling surface to the air, with a weight of not over eighty pounds, when filled with water.

The original honeycomb radiator was constructed with square tubes, and is illustrated in Fig. 56. In these radiators, instead of header plates into which the tubes were soldered, copper wires were simply strung between their ends to hold them sufficiently

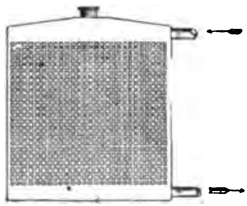


FIG. 56

apart, and the whole soldered firmly together. The latest constructions involve the use of tubes such as are shown in Fig. 57, in which the expanded heads permit of the tubes being assembled together without header plates, the constricted portions of the tubes providing sufficient space for the water to circulate, the corrugations on the tubes further increasing the radiating surface.

To some extent, it has proved possible to construct honeycomb

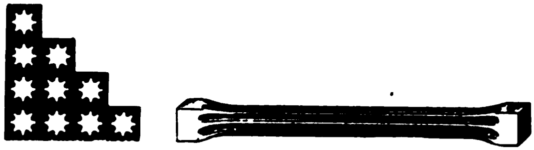


FIG. 57

radiators by electrolytic process consisting simply of plating copper over a properly prepared wax mold, with the wax afterward melted out. Such radiators avoid the two chief objections to the honeycomb construction—the great expense, and the danger of leakage.

The radiator illustrated in Fig. 58 is a modification of the honeycomb type and is widely used. It provided almost as great a radiating area, with very much less complexity of construction. As shown in Fig. 58, it consists simply of a number of wavy, vertical plates, assembled in pairs, with water space between, as as shown in detail in Fig. 59, and the whole assembled together so as to produce practically a cellular or honeycomb radiator.

The radiator construction illustrated in Fig. 60, in which the walls *aaa* contain no water, only those at *bbb* being hollow, is claimed to be quite as efficient, while eliminating some of the complexity of the other types. The heat conductivity of the metal

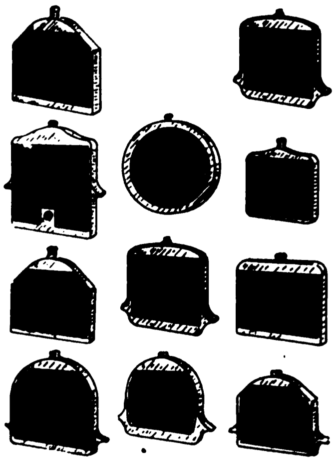


FIG. 58

in this radiator is claimed to be sufficient to conduct the heat of the water-containing walls to the radiating partitions. Nevertheless, it is probable that a wall on one side in contact with water and on the other in contact with air provides for a somewhat more efficient result.

The efficiency of radiating surfaces varies in cacordance with a number of conditions. According to the experiments conducted by one manufacturer, it appears that 38 square inches of radiating surface, exposed to a blast of air moving at 30 feet a second, or 20.45 miles an hour, are sufficient to cool 1 square inch of cylinder-wall area, water being circulated through the cylinder jacket at the rate of 2 gallons a minute, and the temperature of the air being in the neighborhood of 70 or 80 degrees F. For an airblast moving at a less velocity, it is stated that three additional square inches of radiator surface must be provided for each square inch of

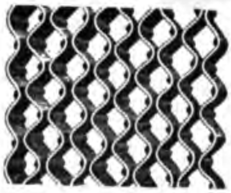


FIG. 59

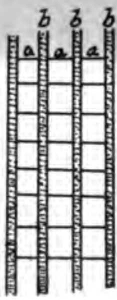


FIG. 60

cylinder-wall area for each 1½ foot reduction per second in the velocity of the airblast.

Circulating pumps generally are provided in cooling systems for keeping the water in motion through the jackets, radiator, etc. Piston, centrifugal, and rotary force pumps are all employed, preference being given the latter, while the first type is but little used. Since a pump in a cooling system does not have to work against much pressure, and the duty required of it is otherwise light, centrifugal and rotary pumps give very good results. The latter usually runs at speeds ranging from 500 to 1,000 revolutions a minute, while centrifugal pumps may be run at as high as 3,000 revolutions a minute. Pumps may be driven either by gear wheels, chains, belts, or friction wheels. It is common practice to mount them directly upon the end of the half motion shaft, or upon the engine shaft, in which cases all complication is avoided. With

slow-speed engines, it probably is better to mount centrifugal pumps directly on the forwardly projecting end of the engine mainshaft.

Thermosyphon circulation is depended upon in many motor vehicles, the hot water rising in the engine jacket, and passing down as it cools in the radiator, being depended upon to maintain the circulation, hot water, of course, being lighter than cold. This system is objected to by many, however, who contend that cool water should be introduced at the top of the engine jacket and forced out at the bottom, contrary to the tendency of flow through thermosyphon action, as it is the top of the cylinder that most needs cooling, and therefore should receive the cool water fresh from the radiator. Many instances exist of the thermosyphon principle combined with the pump in the same system, in which case the thermosyphon action may be depended upon in case of injury to the pump.

An excellent system of thermosyphon water circulation is shown in Fig. 61. The cylinders *a a*, cast in pairs, have large water pipes *b*, fastened in their heads, so that as the water gets warm, it rises without obstruction, and flows as indicated by the arrow to the top of the radiator *d*. As the water cools, it drops through the radiating pipes *f*, and by the time it reaches the lower part of the radiator *e*, it is cold and flows as shown by the arrow through *c*, into the base of the cylinder jackets. As it gets warm again, it rises in the jackets, goes through *b*, etc. A fan flywheel is provided to draw cold air through the tubes *f*.

Fans are used with all honeycomb radiators and with most of the other types, for the purpose of inducing an air draft over the radiating surface, regardless of whether the vehicle may be in rapid or in slow motion, or standing still.

Valves and Piping in a water-cooling system are for the most part but little different from those used in ordinary plumbing. As a rule, all sharp bends and corners, such as might impede the free circulation of the water, are avoided, and care is taken to avoid hollows from which the water cannot be drawn in cold weather and in which it therefore might freeze. Common use is made of rubber-hose connections, instead of rigid metal connections, because greater flexibility is thus provided and the danger of leaks occurring through a strain is reduced.

Anti-Freezing Solutions. Though water is the best liquid for use in a water-cooling system under ordinary circumstances, the fact that it may freeze in cold weather may cause serious trouble —cracked water-jackets, leaky radiators, broken pumps, etc.

For this reason, it is general to use some other liquid as a substitute for water in cold weather. A solution of calcium chlorid in water to a specific gravity of about 1.15 is one of the best anti-freezing solutions in general use. This will stand exceedingly low temperatures without freezing, and, if properly handled, possesses few objections. Zinc or galvanized iron tanks are somewhat corroded by it, but these metals are fast giving way to copper in cooling systems, so this fact is not so serious an objection as it has been in the past.

Glycerine and water make an anti-freezing solution that is in many ways excellent, although it will not remain liquid at as

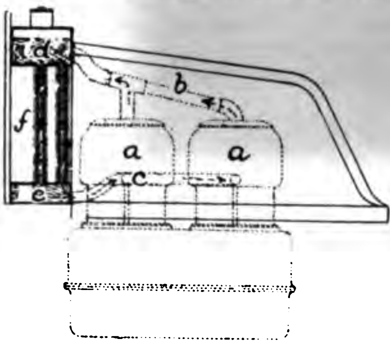


Fig. 61

low a temperature as a calcium-chlorid solution. A mixture of thirty volumes of water with fifteen volumes of glycerine and one part of ordinary washing soda is said to make an anti-freezing solution that is superior to those composed of glycerine and water alone.

Oils of some kind or another are sometimes advised for anti-freezing mixtures, but their low heat capacity renders them very inefficient. This is, perhaps, not a serious matter in the case of continuous cold weather, but under conditions where very cold weather alternates with weather less cold, it will be found that it is dangerously easy to heat up a motor if oil is used for cooling.

Care and Repair of Cooling System. An air-cooling system requires practically no attention to keep it in good order, unless it be fitted with a fan which will call for periodical cleaning and lubrication, and, perhaps, for some attention to the belts or other means by which it is driven.

In a water-cooling system, the circulating pump is often the only moving part, and is therefore the one susceptible to injury. The presence of any foreign substance in the water always should be avoided by the use of a very fine strainer in filling tanks, as a very tiny pebble, or even a little sand, may break or seriously wear a pump through which it passes.

To prevent actual breakage of pumps, one maker provides a small, pronged lever in the pipe that delivers the water to the pump, so that if a pebble or any other object bumps into it, it will immediately disconnect the mechanism that drives the pump, thus stopping it before damage can occur.

Centrifugal or rotary pumps are likely to leak through their bearings as a result of wear. This is especially liable to occur in the case of pumps driven by chains, belts, or through friction, as these systems of driving cause the shaft of the pump to bear very heavily against one side of its bearings, with the result of increasing the wear. Spur gears are in every way preferable, and pump shafts should have long bearings, far apart and close to the driving point. The only remedy for leaky pump shafts is re-bushing.

Instead of with a long, plain bearing, some pumps are fitted with stuffing boxes and glands, packings being used to make a water-tight joint around the shaft. One of the best packings for this purpose consists of alternate layers of rubber and fiber, about 1/8 inch thick, packed closely about the shaft for some distance in each bearing.

Failure of the water to circulate in a cooling system may very easily cause overheating of the engine and serious injury. Therefore, to indicate whether or not a system is working properly a float glass or pressure gauge on the dashboard may be used, to show the force of the circulation to the operator of the vehicle.

Perhaps a better system consists in leading the cooling water through a small tank containing a float that, as it falls, shuts off the fuel from the engine. As the circulating water is pumped into the tank from the bottom and taken out at the top, the tank is certain to be empty if the circulation fails, whereupon the engine will be immediately stopped.

A somewhat similar system employs a valve in the circulating system that breaks the ignition current in case the water ceases to flow.

Still another device consists in a mercury-filled thermometer tube, located in one of the cylinder jackets, which short circuits the ignition system if the cylinder becomes dangerously hot through failure of the circulation or otherwise.

Radiators usually being built of many small pieces, soldered together, and carried in rather exposed positions, are very likely to develop leaks, in which case there is no help but soldering. With a honeycomb radiator this is likely to be a very difficult job, as heat sufficient to melt the solder is likely to permit all the tubes in the neighborhood of the leak to come apart. For this reason, a leak in a honeycomb radiator is a very serious matter, and its emergency repair may require filling the air space with solder. In fact, such a radiator is sometimes built by a dipping process which solders the ends of all the pipes at once.

Radiators, and especially those of the honeycomb and similar cellular types, in which the water passages are very small, may clog up with mud or mineral deposits very easily. Water containing lime is especially likely to cause trouble in this manner, soon producing incrustations throughout the walls of the radiating system, which not only disturb the circulation, but also interfere with the cooling, because of the fact that the water cannot then come into contact with the radiating surfaces.

Rubber-hose connections in a cooling system require occasional renewal. Pieces of hose, of suitable size, always should be carried in the tool box for this purpose, since these rubber connections may break down at any time.

Mufflers and Silencers. Because the exhaust of a gasoline engine is emitted at a pressure of from forty to sixty pounds to the square inch, a very loud noise is produced at the moment it passes into the atmospnere, unless some means for silencing it is provided. Consequently, a muffler is an essential part of almost every motor-vehicle power plant.

There are two principal means of preventing the noise occasioned by the passing of the hot and highly compressed exhaust gases into the atmosphere. One is by forcing these gases to expand gradually, and the other is to cool them.

MUFFLING BY GRADUALLY EXPANDING OF EXHAUST GASES

Most mufflers work upon the principle of gradually expanding the exhaust gases through a number of graduated expansion chambers, provided with walls and baffle plates that break up the escaping charges and set up eddy currents within them, by which the gas is caused to react upon itself in such a manner that it is finally reduced to atmospheric pressure without noise. This process of silencing by dividing the sharp blast into many small and slow-moving streams, doing away with the noise, is very effective, but

it is almost impossible to build a muffler of this pattern that does not produce a back pressure upon the engine. Many otherwise excellent and generally used mufflers produce so marked a back pressure as to offset one-tenth of the power developed by the engine, which is a pretty heavy price to pay for the absence of noise, especially if maximum power happens to be required. This fact has led to the equipment of mufflers with cut-outs, by which the exhaust from an engine may be turned directly into the atmosphere, without the intervention of the muffler, in case difficulty is experienced in climbing a hill or proceeding over other bad going.

SILENCING BY COOLING EXHAUST GASES

Since the pressure and consequent tendency to expansion of the charge in a gasoline engine is caused by the heat imparted to it by combustion, cooling such a charge while it is escaping will reduce it to its original volume and thus avoid noise as it issues into the atmosphere. Several means are in use for cooling exhaust gases with a view to silencing, but the most effective depend upon simply dividing up and mixing the gases with surrounding air before permitting their escape, or upon air cooling the muffler. Silencers of this type are not much used, but they seem likely to become generally used, as their principle is more widely understood.

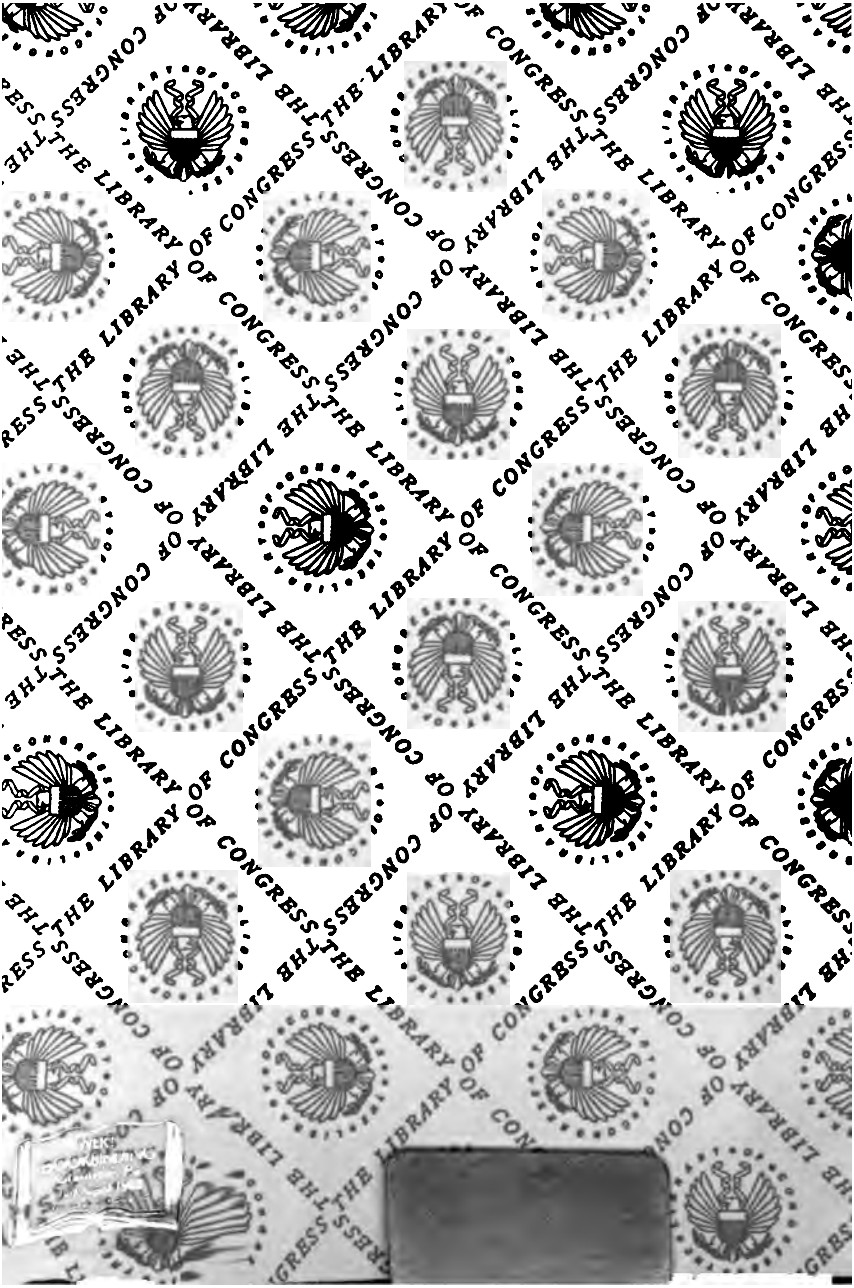
MUFFLER TROUBLES

Practically the only difficulties experienced with mufflers and silencers are their bursting and their cracking. The first occurs from the passage of an unconsumed charge from the engine into the muffler, as a result of ignition failure, etc., with the result that it is ignited by a succeeding hot exhaust, or by the hot walls of the muffler. Such an explosion is never sufficient to do serious damage and often occurs without harm resulting, but it may rip open some of the sheet metal plates of the muffler, enough to cause leakage.

Some mufflers are provided with relief or safety valves, which normally remain closed against the pressure of the muffler, but open when an explosion occurs, so as to let the gases escape without doing damage.

Exhaust pipes and mufflers may become choked with soot, in case an engine is run with too rich a mixture or with a fuel for which it is not adapted, and an accumulation of this sort may set up a serious back pressure. In such a case the remedy is a simple

one, consisting in a thorough cleansing, which will be easy or difficult, according to the design of the muffler. If it is not possible to introduce a brush or scraper into all parts of the muffler, or to take it apart, it may be detached and kerosene or gasoline passed through it. If this is done, care should be taken to dry out every vestige of the inflammable liquid before the muffler is used. Soap and water, or a strong lye solution, is a fairly good liquid for cleaning a dirty muffler.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